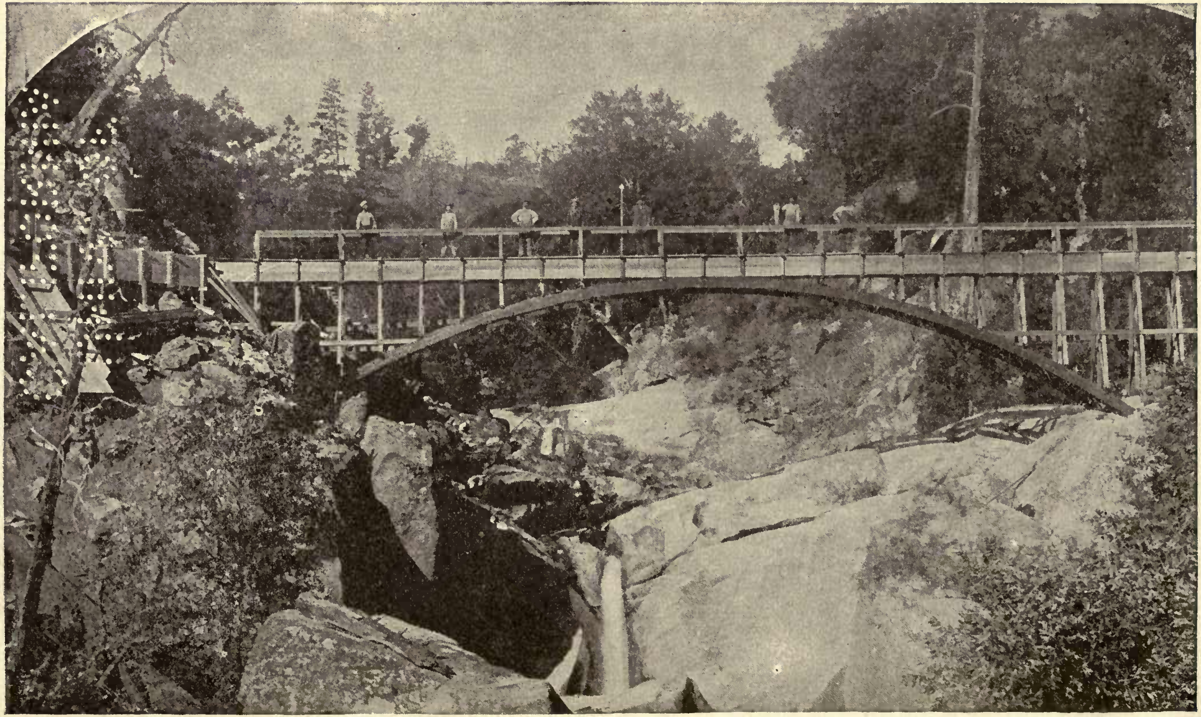

Frontispiece.

HYDRAULIC AND PLACER MINING.

BY

EUGENE B. WILSON

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PREFACE.

THE present activity in placer mining arises from the unprecedented demand for gold.

Simultaneously with this demand, new sources of supply are discovered, and obstacles which in California, at least, temporarily prevented placer mining have been satisfactorily surmounted. New and improved machinery has been introduced, which admits a wider range of such deposits being exploited.

The author here acknowledges the kindness of the Risdon Iron Company and the *Mining and Scientific Press*, of California; also the *Scientific American*, of New York, for illustrations which appear in this book. He is also indebted for information to the manufacturers whose names are inserted.

The method of presenting the subject-matter, he trusts, will be of substantial benefit to those interested in placer mining.

E. B. WILSON.

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HYDRAULIC AND PLACER MINING.

CHAPTER I.

HYDRAULICKING.

HYDRAULIC MINING, strictly speaking, refers to breaking down material from its natural bed by water-power.

Such definition at this date would necessitate the framing of some word which would include breaking down, transporting, washing, elevating, dumping, and concentrating. The term now embraces a wide field, from washing the material in miners' pans to expensive appliances and machinery.

To cover the subject properly, mining, civil, and hydraulic engineering, as well as a knowledge of machinery, is required.

The most difficult problem, however, is to find the gold to be worked; the remainder can be bought, although it covers, at times, intricate engineering problems.

To spend a million or so dollars upon engineering

problems for water-supply, to work gold, which is not, has been done; consequently, the most difficult task is to find the gold and ascertain as nearly as possible how large an amount there is of it, and whether its working will warrant the outlay demanded.

The value of the property having been determined, it may be necessary, to work it successfully, to construct flumes, pipe-lines, and ditches from one to one hundred miles in length, and in doing so it may be necessary to tunnel mountains, span chasms, siphon across valleys, bracket flumes to the side of the cliffs, build reservoirs and dams, and finally, settling dams. In other instances, steam-shovel dredgers will be all the engineering required.

To attempt to give details upon all the matters which may become involved in the subject, or all the scientific principles put to use, is impossible—no one book could accomplish the matter, consequently the information will be general, but of such a character the engineer will know how to proceed, the investor what must be done, and furthermore, why the engineer is compelled to take certain steps requiring the outlay of money.

Hydraulic mining brings uppermost to the mind "gold placer mining," since the latter was the chief incentive which produced the many ingenious contrivances now known for "hydraulicking."

Second thought widens the field, and, with gold uppermost in the mind, suggests "river dredging," and the contrivances for that purpose.

Hydraulic mining, in a more lowly sense, is a matter of some moment. To stop here and not suppose that hydraulic mining is useful for iron and salt mining, and also that the use of water is an adjunct at times to quarry-work and coal-mining, is to believe that gold has a monopoly of the subject.

The use of water for mining dates back to King Solomon's time. Agricola informs us that fire was used to heat the rocks, and then cold water thrown on them to spall them off. In quarrying where seams exist in bedded rock, and where explosives would be apt to shatter the rock being quarried, water is employed with wood.

The method here followed is to drill a series of holes back from but parallel to the face, on the line of cleavage. Into these holes wooden wedges are driven. These wedges, on being wet, expand and split the rock as desired. The method of spudding generally in vogue does not always answer as well as the wedges mentioned.

The danger which arises from the use of gunpowder in gaseous coal-mines has produced two classes of expansive cartridges which depend upon water for their utility. The coal is undercut in the usual

manner, and holes drilled in the section to be broken down.

1st. Into these drill-holes cartridges of compressed quicklime are inserted, after which they are moistened, then tamped. The water used to moisten the lime causes it to slack, expand, and generate steam; this combination breaks down the coal. The economical value of this novelty has not been fully established in this country. The number of drill-holes and lime-cartridges would possibly bring the cost of the process up to that of powder; however, the smaller undercut, and the reduction in the amount of slack coal produced, compared with powder, may counterbalance previous objections. The distinctive advantage which this process possesses is the avoidance of explosion from gases in mines which are subject to outbursts of gas.

2d. The water-cartridge of the second type is metal and to be used as the former in fiery coal mines.

It is a metal wedge, so contrived that upon the application of hydraulic pressure it will expand.

To break down the coal a series of wedges are connected, so that when the pressure is applied it is uniform on all. The cartridges being indestructible, may be used over again. They have not come into general use in this country. Cartridges of this description, which could be used from water-pressure at

the mouth of some metal mines in the West, would be a great blessing, in preventing the fouling of air and loss of life, not to mention economy in the matter of powder, time, and fuse. Their use would be limited to overstopping.

Salt-mining uses water in practical ways as follows:

1st. As a solvent. For this purpose a series of bore-holes are drilled from the surface down into the deposit by percussion or diamond drills.

Water is then run into the holes and allowed to become saturated with salt, after which the brine is pumped out and more fresh water run into the hole.

By a series of these bore-holes near together an underground cavity or water-course is soon formed in the salt-bed which connects the holes. Dynamite is useful in assisting the connection. The water, after the connection is made, flows in continuously and is pumped out at the same rate it enters. The working is now permanent, one bore-hole supplying the water, and another fitted with a deep well-pump removing the brine.

This method has advantages, in some instances, over any other method of mining salt where the material is to be broken down, hoisted, dissolved, and then concentrated. It also offers the further advantage of leaving the impurities in the mine, and brings the article sought in the proper concentrated form for refining.

2. Probably hydraulic mining originated in the salt-mines of Europe (to which the term "spatterwork" was given), as there it has received considerable attention. The water used for mining is given a gravity-pressure and ejected from a nozzle having a number of small orifices. The water from this nozzle strikes up against the salt deposit and wears it away; at the same time, in flowing away it dissolves the salt, leaving the worthless débris to be broken down or removed. The brine is then collected by gravity in sumps or subterraneous reservoirs, from which it is pumped to the surface and evaporated.

Spatterwork can be employed for sinking shafts from a higher to a lower level, or making "rises" from a lower to a higher level. Gangways or rooms

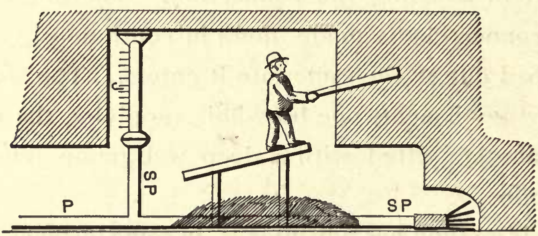

FIG. 1.

may be driven in such deposits by this method, as crudely shown in Fig. 1. For side-cutting, the main supply-pipe for water has coupled to it, by a hose, a stand-pipe, *S. P.* This pipe is wedged between the

roof and floor, in an upright position, with the orifices directed toward the face of the ground to be attacked. The water wears away the deposit both by dissolving and mechanical power, and it recedes from the stand-pipe and the orifices of the water-jets until the projective force is expended. The water is now turned off and the column-pipe placed in another position, where the water by its projective force, together with its solving action, can perform more effective work.

The same illustration shows the method of undercutting the deposit of saliferous clay. The spatter-pipe is placed upon the floor so that it may be moved forward to deepen the excavation, or laterally to widen it. The undercut having been made, the saliferous clay is easily wedged down, where it may be acted upon by a stream of water to dissolve the salt content and leave the barren dirt. The use of water is limited to the amount required for the pumps and for saturation of the brine. It may, in some instances, be used on one level and carried to the next lower, and so on, thus attaining the requisite saturation before reaching the pumps and sumps.

Wherever the latter conditions prevail, shafts or risers may be made as roughly sketched in Figs. 2 and 3.

To drive the shaft, it is necessary to sink a bore-

hole from the shaft above to allow the escape of the water discharged from the nozzle, *n*. The water from the supply-pipe on the upper level acts by gravity, and propels the water from the jet-holes in the nozzle against the sides of the shaft. It is evident in this instance that the action of the water increases its pro-

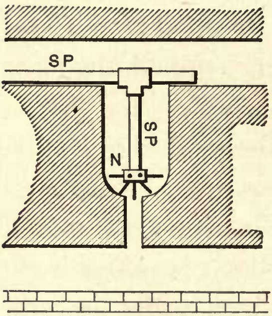

FIG. 2.

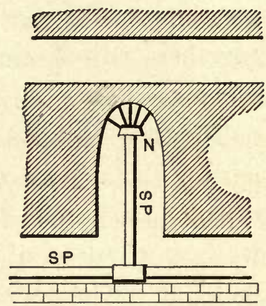

FIG. 3.

jective force with depth until it reaches its maximum when the lower level is reached. Fig. 3 shows the drifting of a "rise," and has the reverse in water-projective force as it nears the upper level. To facilitate this latter method, water is brought under pressure greater than the height to be driven.

Mr. Oswald J. Heinrich stated that with 21-foot head of water, and side-cutting from a spatter-pipe having brass orifices 1–2 mm. diameter and 12 in number, the advance was 0.6 sq. ft. per minute, with 1 cu. ft. of water per minute. One man attends to

12 spatter-pipes in a 12-hour shift. This rate of excavation is in round numbers 5184 cu. ft. per day, with 8640 cu. ft. of water and one man's labor, thus comparing favorably with any hydraulic mining, as it is 0.52 c. per cu. yd. for labor and not as high in amount for water as gravel mining generally.

Iron ore deposits of an alluvial character, such as are the "brown ore" deposits of Virginia, can be worked to great advantage by "hydraulicking" if situated on side-hills. In such instances the ore is disseminated through clay with barren rocks in such a manner as to need both concentration and washing. It may be necessary to wash 10 tons of such material to concentrate one ton of ore. The cost of excavating and handling such stuff would make the ore-bed commercially unprofitable, if freight must be added; it has, however, been practically demonstrated to be more economical to burn fuel and pump water uphill and hydraulic than to work by the former method. To illustrate this more fully: to pick, shovel, and transport such material to the washer, wash it, and load on cars will cost, for 10 tons, $2.00—*i.e.*, one ton of iron ore.

To accomplish the same work with water having a head of 50 ft. will cost 75 cents per ton of iron ore. The "hydraulicking" system materially lessens the work to be done by the washer, as the ore becomes

freed in a measure from clay as it travels through the sluices to the washer.

There is one more system of water mining made mention of by Pliny in his "Natural History." It has been practised somewhat in this country, and is termed "booming."

The process of "booming" is to make a dam and collect water; whenever the dam is full the gates are opened quickly, allowing a torrent of water to rush down the hill and upset matters generally. The water, having done its work, is led through sluices which are nearly on a level at the foot of the hill; in these sluices the gold washed out of the soil is collected. Water is employed for many purposes not directly under the heading of this book, so that the term hydraulic engineering embraces a much wider field than it did twenty years ago, and is continually expanding.

CHAPTER II.

GEOLOGY OF PLACER DEPOSITS.

PLACER deposits are alluvial deposits, located by the action of water or glaciers.

These alluvions are composed of clay (formed from the disintegration of feldspar and silicious matter in rocks), quartz pebbles, rocks of various description and sizes, gold in a small proportion to the whole mass, and whatever else may have been deposited—trees, sand, or fossils. These depositions have taken place through ages, and by the disintegration of gold-bearing rock time has at last allowed the gold itself to be worn away by the natural elements—wind, heat, cold, and water; but here and there are indications that glacial action alone has been the source from which placers originated.

What appears to have been the chief element in the location of placers, also in their formation, is water; and alluvions in deep deposits are conceded to have been formed by the ancient tertiary rivers' action on the gold-bearing slates (or, as they are termed, "auriferous shales") and rocks. Later rivers have cut

channels through the ancient river-beds and formed new deposits not nearly as rich and more spotted.

California gold was probably first crushed and milled from quartz veins of the Sierras by glaciers, then washed by the ancient rivers. These ancient river-channels were cut into and in part washed away by modern rivers and creeks, along the sides of which are found bars and benches containing the gold. "From these California deposits more than $500,000,000 in gold were taken out in ten years. In Siberia and the Klondike nature has only had the first of these agents at work, viz., the glaciers, and there has been no concentrating by ancient rivers. The natural inference would be in California that such deposits, originating from gold-bearing "rocks, if traced up would lead to the discovery of the 'mother-lode.'"

This is frequently the case, but nine times out of ten the mother-lode does not contain free gold in anything like the proportion or size of grains that the placers indicate. The writer has found the original rocks in Virginia and elsewhere, which will not show gold to the naked eye, and at times not with the magnifying glass; yet it is there, and in quantities, by fire assay analysis. Professor Phillips gives instances where placer deposits came from rocks through which gold was disseminated but was not in vein form. The Breckenridge Colorado placers have produced consid-

erable wire gold, and the mother-lode is traced with reasonable certainty; yet the vein has never paid when worked.

The placers of Louisa County, Virginia, from the vicinity of which came the celebrated Carrubus nugget, are most uncertain; yet from that locality came the gold ore which won the prize at the Centennial. California Gulch yielded considerable placer gold, but the mines at its head, near Leadville, produced mostly silver, and nothing to compare with the gold up to the present time. Leadville district is peculiar, and its mines produce almost any metal demanded, from iron ore to gold; so it is not safe to speculate that it will not produce as much gold from the mines as from the Gulch.

The richer placers of California did not lead to important quartz mine discoveries, for it appears from recent developments that they never paid much attention to quartz mining; consequently, the "mother-lode" will undoubtedly produce rich mines.

The history of placer mining is such that to trace up a placer and find a rich free milling-ledge is not the rule, but generally a surprise to the fraternity. The Klondike may prove an exception, but there they could not work a ledge if found.

Rich veins have been discovered where no traces of placer gold could be found. Gold has been found in

grass-roots directly over a vein; but this should not be termed placer gold in the sense in which this term is construed at present. That gold should be found in paying quantities and in sizes from pin-head up in placers, while not found in the mother-lode in similar quantities and sizes, would seem mysterious, and, if some placer miners are to be believed, "it grows."

This latter statement miners will illustrate as follows: In 1875 California Gulch was washed and $20,000,000 in gold was recovered; when it was abandoned one could not make wages. Of course, some seeds were left, and in 1885 it was washed again and $5,000,000 recovered, the inference being that it grew. The explanation that possibly millions of tons of gold-bearing material were concentrated in that gulch by Nature, and that the second washing was only the leavings of the first, will not satisfy the miner, who will probably paraphrase Job and reply, "There are veins of silver; but the place for gold is where you find it."

Water having been the chief element in forming placer deposits, has in some instances carried the gold many miles down a sloping hard river-bed, and eventually formed "alluvions;" in other instances the distance travelled has been short.

The gold may have moved slowly down the sides of a mountain and be found parallel to the mountain

range, or it may be in narrow channels, as in gulches. The specific gravity of gold is sufficient to sink it in a comparatively swift stream of water on an incline. If the bottom of the stream be rocky it will fall between the rocks and become cemented in by the material which follows; thus it is usual to find the "pay-dirt" near bed-rock. This, however, does not signify that a bunch of pay-dirt will not be found above this bed-rock—in fact, anywhere through a deep moraine—since the action of the water continued some time. If the water was not sufficiently strong in its movement its next deposit would be gravel and sand. In latter years (the action of the water in former years having filled up the beds) any little freshet over the former deposits would cut a small channel into which the travelling gold would sink. This system of concentration formed, not wide deposits, but narrow ones, from one foot up to several hundred in width; but in the latter instance we cannot speculate with any certainty upon the gold being uniformly distributed through the deposit, while we are fairly safe in considering that the reverse is the case, especially if in a valley. The original alluvions may have been washed out and spread broadcast by some torrent followed by an upheaval which put an end to the water flowing in that direction, leaving only such formations and narrow deposits as are in places found.

Placers are now found, for this particular reason, where no water of any amount is to be had, and in such localities as to be termed "dry placers." In washing gold gravel it is not infrequent for one miner to have a rich strike while another a few feet away is not making wages. The miner is therefore very cautious in following up his "pay-streak" in such instances. Gulch mining is particularly uncertain on the latter account, very frequently the richest dirt being along the sides, and not in the centre of the gulch.

The character of the "placer dirt" varies considerably in localities, but if it be of any material thickness it will contain hard-pan—that is, clay, gravel, and large stones. This is difficult to pick and shovel, and usually mean and sticky to wash. If wet, it is worse yet to handle, as in some instances it seems to melt up, and if dry, bake up.

No one can with absolute satisfaction explain the various distributions of gold in placer deposits.

At times the gold may be fairly uniformly deposited through the dirt, again in layers. It may be found from the grass-roots to bed-rock, but in the majority of cases in the latter situation. Each alluvial deposit has different characteristics for each locality, and as the substances of which they are composed vary, the location of the gold must vary.

The thickness of "placers" varies from a few inches

to 650 feet; one deposit may have one pay streak, and another several.

Generally, when a pay-streak is on bed-rock there may be depressions in the rock which will prove very rich, at other times not. Where eddies have occurred in the alluvions rich ground may be found, and at other times not. Usually the fine sand is not as rich as the coarser, and to this may be attributed some failures in dredging river-bars or float-sand, where if the present dredging system had been employed the results would have been satisfactory.

The sampling of placer gravel-beds for hydraulic mining is a matter requiring considerable research before arriving at a conclusion.

Some persons may be satisfied with washings from ten or a dozen small holes, and from these calculate the value of the placer-ground; one Klondike estimate was based on a 16-foot hole and a 6-foot drift for a 1000 x 500-foot placer. Such estimates may suit in Klondike, but not in this country, and is "bluntly" unreasonable. Mining engineers will not attempt it; promoters will not base calculations upon such exploration, consequently the schemer with a more extensive knowledge of the dictionary than of gravel deposits is the only one who can calculate in this manner.

To determine the value of a gravel bed it is neces-

sary to examine the topography of the country, and calculate from exploration its length; the next important matter is to ascertain the depth of the deposit to bed-rock; finally, the position of the channel and its course, considering that gold will naturally be deposited along the channel, and will in the lower alluvions conform to bed-rock. We have now, as a basis for calculating the amount of gravel, the necessary data, but lack the value of the pay-streak.

If the deposit be deep and bed-rock cannot be drifted on, shafts should be sunk and the pay-streak worked across the entire bed-rock, and for a considerable distance along its channel.

The washings from the dirt so excavated will give the value of the pay-streak per cubic yard as closely as may be determined. The thickness of the pay-dirt, its length and breadth, being now known approximately, its value may be calculated by the known value per cubic yard.

This, however, does not give the value of the whole mass of gravel per cubic yard which is to be worked. The total value being calculated for the pay-streak, the total number of cubic yards of the deposit is divided into it, thus giving the unit value per cubic yard of gravel to be worked.

The value of gravel per cubic yard of placer dirt should not be calculated in any other way or ex-

pressed in any other terms than in the unit value relative to the whole mass.

In thin deposits tests may be made over the entire portion in sections, by a series of shafts, or rather holes, across and lengthwise to cover the entire area of the deposit. The average returns from such tests will give an approximate value of the placer; if the test is at fault, it is generally on the safe side. The length and depth is readily ascertained, and the width as well, thus arriving at the cubic contents, of an average value as determined by the test-holes.

In case of more than one bench of pay-dirt, the two methods may be necessary to express the unit value of the deposit.

There are two more factors which must be ascertained before we can value the deposit as an hydraulic proposition for investment. The first is water in ample supply to break down and sluice the deposit, and the estimated cost of leading the water to the gravel bed. This requires the engineering skill referred to in a previous chapter, and embraces not only the survey and route for the water-course, but reservoirs and dams, and the estimates for their construction, which of course cannot exceed the value of the placers to be worked.

The second factor is that sufficient fall to the dump may be had immediately below the workings, to carry

away the barren dirt or at least prevent its accumulating in the way so as to be troublesome. The basis for the work may be now said to be complete, if the different factors are within reasonable limits of the estimated values; but care should always be used in overestimating work in a rough country, and in gold-washing underestimating values to be obtained, since matters in the first instance cannot always be definitely calculated beforehand, while it is not generally a rule that the savings are as close in sluicing as in pan or rocker washing, which are generally used to estimate values.

CHAPTER III.

GOLD RECOVERIES BY VARIOUS METHODS.

THE Romans practised sluicing, and according to Pliny the shores of Spain were added to by "booming;" from this we may suppose that hydraulic mining began with creation.

Present hydraulic mining for gold originated in California, the miner's pan giving way to the "rocker," the rocker to the "long tom," the long tom to the sluice-ditch, the sluice-ditch to the sluice-box. Corresponding to the advantages of the sluice-box over panning may be mentioned the stream of water for excavating over the shovel.

Panning.—The ordinary gold-pan is an imperfect appliance for saving fine material, but an excellent tool for free gold, since the angles of the sides collect it, while allowing the sand and lighter particles to float off.

The placer dirt is shovelled into the pan and the whole immersed in water. The gold being specifically heavier than the sand, or clay will sink to the bot-

tom of the pan. There may be gold enclosed in clay or cemented in sand; or, again, dried to the rocky contents of the pan; therefore, to loosen the adhering gold, the material is soaked. To hasten the loosening of the gold, the contents of the pan are stirred slowly with the hand, which allows the slimes loosened to rise above the pan and float away. As the water becomes clearer in the pan the largest stones are picked out, and the agitation made more brisk to float out the sand; this is continued until but little sand remains. An apology for a cut of a gold-pan is here made (Fig. 4), but it is for the sake of comparison with the batea. Gold enclosed in the rocky matter is not recovered by this method; it may be pulverized when discovered and then panned. In this latter instance the recovery becomes scientific, and is virtually pan-assaying. The pan for this purpose should be black, and in the shape known as the batea or vanner-placque.

The pan is held firmly by one hand, some water is then poured on the pulverized ore; the other hand is used now for shaking the pan in a gentle but rapid manner. The powdered ore being gathered to one side, the heavy grains of gold descend through the sand to the bottom of the pan and settle. After shaking the pan a few minutes, it is to be moved so as to produce a gentle current in casting off the water.

This will carry off some of the sand and diminish the quantity in the pan. Fresh water is now added, and

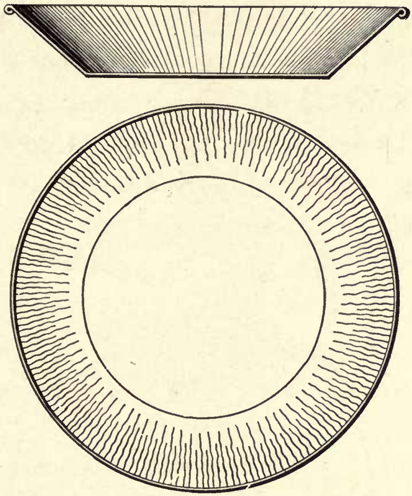

FIG. 4.

another portion of sand washed away, this operation being repeated until nearly all the sand has been washed from the pan. A little water being retained in the pan, it is moved around by inclining the pan; this gentle current will carry the sand with it and leave the metal in view. Assaying by the pan is not accurate, as only the coarser particles are retained, the finer going off with the sand. At times it is customary to rock the pan back and forth with the last water slightly and then make a fan-shaped appearance with

the material remaining by inclining the pan to one side. The gold being the heavier, remains in the centre of the pan at the point of the fan. If a batea with a hole in the centre has been used for the operation, the gold may be separated from the sand by pushing it through the hole.

The Mexican batea (Fig. 5) is considered a good tool for placer miners, but it does not possess advan-

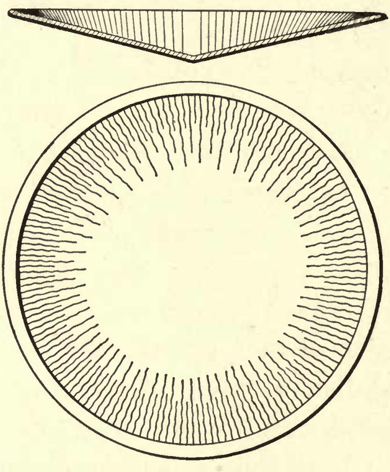

FIG. 5.

tages over the iron pan, except, perhaps, in the matter of collecting sulphurets in sample assaying. The wooden bowl is given a steady circular shake without revolving, alternated with a reciprocating motion, which settles the heavier mineral in the centre of the

bowl; on inclining it now the sand flows to one side. The batea is used by the Mexicans for placer dirt only when they cannot get the iron pans. In washing placer dirt they are filled as above with the dirt, immersed in water, and stirred by hand; a circular motion is given to the bowl, which is also slightly inclined, allowing the sand to wash over the sides. The gold sinks to the bottom and clings to the sides of the batea, which requires, generally, more care in manipulation.

The American miner considers the batea an excellent hash bowl, while the mining engineer gathers them for "curios." To work either the pan or batea requires care and experience; some become very expert in their use.

The rocker is an improvement on the pan wherever a placer has been considered good enough after experimenting with the pan in locating.

A cross-section is given in Fig. 6, and another in Fig. 7. These rockers require considerably more water, and vary somewhat to suit the particular ideas of the miner. There are various methods of hanging the cradle, so that a side motion similar to that of a cradle is given; the full pendulum-like swing is intercepted, so that the rocker receives a slight jar which assists the gold in settling to the bottom of the contrivance. The rocker is made of wood, about 6 feet

long, 24 inches high, and 15 inches wide in the bottom, and 19 inches wide at the top (Fig. 6). The

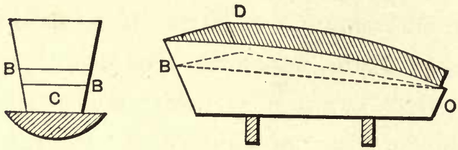

FIG. 6.

rocker is placed on a slant, with the feed-end about six inches higher than the discharge. This inclination should depend upon the material to be washed and the amount of water available. Fine gold should have less water and inclination than coarse. Iron

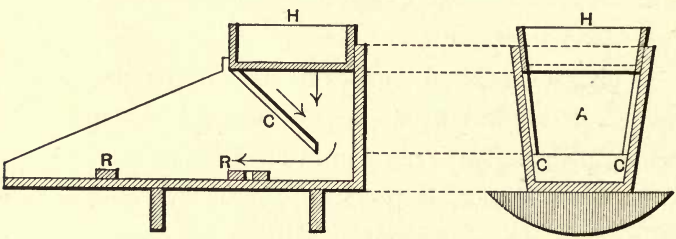

FIG. 7.

bars, *B*, parallel to the sides of the trough, are placed edgewise, making a grating, known as a "grizzly." These bars have end rests, and if too limber or given to buckling should be confined by centre rests. The spaces left between them are from $\frac{3}{8}$ to $\frac{1}{2}$ inch. Perforated or slotted metal plates are more convenient

and will answer the purpose as well, besides being more economical if well braced across the rocker. A current of water is let in at the upper end of the rocker, *D*, on the ore; this water passes underneath the grating, carrying the finer material, sand and gold, with it into the section, *C*. If the gold is fine, quicksilver is placed in the trough, *C*, in small quantities to form amalgam with it. The light sand in *C* is swept out by the current of water which passes through the grating at *O*. At each swing the coarser dirt which does not go through the bars moves by the jar down towards the discharge, *O*. This jar may not be sufficient, however, to remove it; whenever this happens the miner uses his shovel. While these operations are quite effective for coarse gold, there is much fine and floating gold lost even when quicksilver is employed. This is especially the case when much clay is present, which encloses both coarse gold and fine, for the specific gravity of the two combined is less than for gold alone, and the density of muddy water may assist in buoying the fine particles, which consequently in the agitated current float away. Mercury cannot reach fine gold incased in clay if it comes in contact with it; it may be worth while, therefore, to go slower and use more water.

Where there is much clay a good plan is to feed the material and water into a trough and allow the

dirt to be moved by the water along the trough and discharged into the rocker. The clay will be washed more thoroughly from the gold, and a better opportunity to form amalgam given it.

There is another form of rocker shown in Fig. 8. This is a box with sloping sides, about 36 to 42 inches long and 16 inches wide, with rockers at the middle and back ends. The upper end has a hopper, *H*, 20 inches square, 4 inches deep, iron bottom perforated with ½-inch-diameter holes. This hopper is

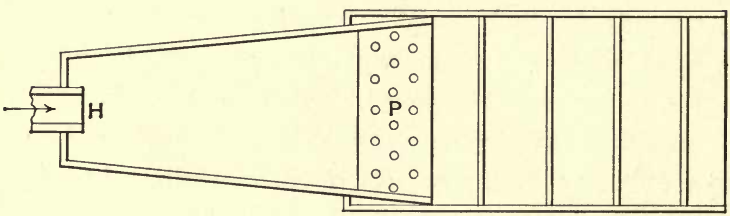

FIG. 8.

removable. Under this hopper, on an incline, a light frame, *C*, upon which a canvas apron, *A*, is stretched, forms a riffle over which the gold travels or is caught. The water is poured on the dirt which is shovelled into the hopper, washing the gold and sand down through the screen, after which the coarse material in the hopper is thrown aside and new dirt substituted. The rocker has at times pieces of board nailed transversely across the bottom, *R*, to catch gold as the current bears the

sand along to the discharge end. These strips are termed riffles.

The "long tom" is virtually a sluice with a perforated plate or grizzly of sheet iron. It is made with the feed end smaller than the discharge end, and these also vary to meet the views of the operator. They are usually fed from a sluice-box, *S*, which is supplied with an abundance of water, sufficient fall being given to move the material (Fig. 8).

As the material enters at *H* it spreads out until it meets the plate *P*, when it is immediately assorted, the fine dirt falling with the water into a box, *B*, underneath the plate. The coarser material is shovelled off the plate. The constant movement of the water in the box under the plate keeps the sand suspended and allows the gold to sink. This removal of the sand may be assisted by sloping the box, together with an occasional stirring up of the contents of the box with a stick or shovel.

Sluicing.—The term "sluice-box" was applied above to a trough which sluiced—*i.e.*, conducted the water to the "long tom." This application of the word sluice will no longer apply in hydraulic mining, since in miners' parlance the term sluice means the troughs, cuts, or boxes through which the mined material is carried by the water, and in which it is washed and the gold removed.

The sluices are now used where large alluvial deposits exist. They may be rock channels, or ditches having gravel-bed channels, or they may be wooden boxes. Their sectional area will depend upon the amount of water to be used, together with the dirt they are to wash. They should be straight as possible, but where curving is necessary the outer edge of the curve should have an elevation, to assist in lessening friction when the direction is changed and prevent piling up of the material. There should be at least one inch elevation for each degree of curvature, but even this will not in all instances prevent retardation after the curves have been passed, making it necessary to give a slightly greater fall below the curve in order to obtain uniform flow of material and clear the curves.

The grade necessary to give a sluice will depend upon the character of the alluvions ; large, heavy stuff will require a greater incline than light material. The amount of water at command will influence, in a measure, the gradient, and the sectional area of the sluice must also depend upon it. The heavy material must be covered by water, and a steep enough grade given to have gravity give velocity to the water and exert some little action upon the material itself ; naturally, then, were the sluice broad, 23,000 gallons of water per minute might be required, where with but half that supply of water the sluice must be nar-

rowed or otherwise a very steep gradient given it. Narrowing the sluice would be the most satisfactory arrangement.

The length of the sluice depends upon dumping-ground and its distance from the workings; yet, were the dump close at hand the sluice must have sufficient length to thoroughly wash the alluvions, break up the cemented gravel, and soften the clay.

The size of a sluice is to be determined by the amount of gradient at command, the character of the material, and the quantity of water which may be used.

The grade of a sluice will depend upon the fall of the ground to the dump, the character of the material transported, and the amount of water at command. The grade will vary from 2 to 15 per cent,* and must be determined previously by experiment before permanently placing the sluice in position, otherwise there may be considerable loss of both gold and amalgam, to remedy which may require the raising of the whole sluice-line, or, if the fall is not sufficient, the lowering.

As low as 1½-per-cent grade has been used. The sluice has advantages over any other system both for collecting free gold and the removal of barren dirt in an economical manner, consequently the attention

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* Bowie, Alex. J., p. 219.

given to its construction and the work it performs will prove remunerative.

Where the gravel is carried any considerable distance it is usual to step the sluice—*i.e.*, make a drop of a foot or so perpendicular; this has the effect of disturbing the material, which, if fine sand, is apt to move along the sluice in too compact a manner. At intervals, as well, riffles are placed in the box. Where the sand is fine, false bottoms of 1½-inch plank with interstices of ¼ inch between them are laid crosswise to the length. Into these spaces mercury is poured. Sand is moved over the mercury without being disturbed, while fine gold is attacked and coarser gold sinks through. Scale gold will escape over several riffles or mercury traps before being captured, and amalgam particles will float away unless these traps be cleaned frequently.

Where coarse material is washed block riffles are employed, and are considered by A. J. Bowie to have advantages over any other:

1st. Because of the cross-riffle they make.

2d. Their cheapness is an item.

3d. They are convenient to clean up.

These block-riffles are squared, and from 8 to 13 inches high. These squares are placed in rows across the bottom of the sluice, separated by a space of 1 to 1½ inches, according to the strips used to keep them

in position. The riffle-strips are nailed to the blocks across the sluice-box to keep them in line; the blocks are also wedged against the sides of the box as an additional precaution against their moving. They are also fitted to break joints and not extend the entire width of the sluice, to meet the operator's views. Stone riffles are at times used. These stones must be quarried to a proper height and size; although at times they are irregular, it is not advisable, since a uniform riffle has proved more satisfactory.

Riffles are made generally to conform to the ideas of the operator, but those mentioned will probably prove economical and give general satisfaction. Locality and means at command must govern the character of riffle employed, but the object is to allow the gold moving along the sluice-bottom an opportunity to settle and enable the operator to know where to find it.

If sluices are long, and riffles and amalgam traps used, it may be necessary to have patrols on sections to keep a watch over the riffles and prevent the boxes becoming choked by débris, and to observe that no leak occurs, with the consequent loss and trouble therefrom.

As dumps are usually in hollows, they become filled up, requiring an extension of the sluice-box, from time to time, on a straight line or a curve.

The subject of riffles would not be complete without mention of the Risdon Iron Company's patent riffle, a section of which is shown in Fig. 9.

The object of such riffles is to create dead-water under them and save such fine gold as mercury will not readily hold and rusty gold mercury will not attack. Incidentally, in accomplishing this purpose they do away with the use of mercury, and hence loss of quicksilver and amalgam; further, they are more

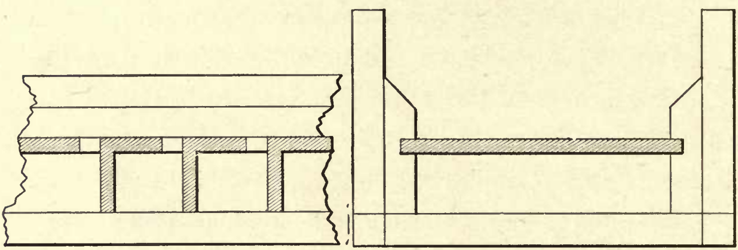

FIG. 9.

easily handled and cleaned up than the ordinary riffle. The amalgam retort is abolished, and the gold itself is purer, and hence commands a better price.

The riffles are made of angle-iron, for any width of sluice desired, but two feet in length of sluice, so that such sections can be readily removed for cleaning up. The angle-irons are fastened at each end to the box, and are spaced one with the other, so that any gold

passing down the sluice along the bottom may fall into the spaces thus created. As no water comes in except from the openings or spaces, the water under the riffles is dead, allowing fine gold to settle and remain in the trap until removed at "clean up."

Undercurrents are produced in sluice-lines to relieve the main sluice of fine material and catch the gold. For this purpose a "grizzly," or set of bars, is placed across the sluice through which the finer material and gold passes.

Underneath the bars is a shallow box made of wood, four to ten times the width of the sluice, and high enough to contain the material washed into it. It is paved with material which will stand wear and answer as riffles. The inclination given this box is considerably more than that given the sluice, according to the smoothness of the floor, and this is gradually diminished as it delivers the material to the sluices at a lower level (Fig. 10).

After the material has been washed through the bars it is distributed over the entire box width by the riffles; the box gradually narrows towards the discharge end, to conform to the width of the sluice into which it discharges.

The "grizzly" should not allow the entire amount of water to pass through it; enough must remain in the sluice to prevent the bars clogging and to carry

the coarse stuff along to the sluice proper again. In California the length of a sluice-box is 12 feet, and the grade is the fall in inches for this length; as this arrangement is a local affair, the grade given in this book is the number of feet fall in one hundred feet—

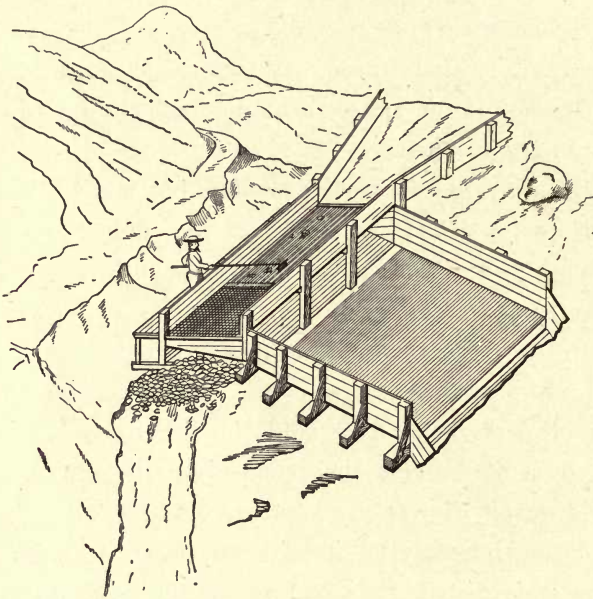

FIG. 10.

thus one per cent means a fall of one foot perpendicular in one hundred feet horizontal measurement.

The construction of a sluice-box depends for details upon the size required; one 6 × 3 feet would require heavier sills and flooring than one 3 × 1.5 feet.

The sills should be three feet apart and be twice as long as the width of the sluice.

The posts are regulated in height to accommodate the water and material; in this connection it may be stated that wide sluice-boxes lessen the water-pressure on the material transported, and are therefore more satisfactory. However, the character of the material must determine, in a measure, this point. The bottom planks should be made of clear lumber and grooved to admit of a dry pine or other tongue being inserted into the groove. These planks are placed lengthwise of the sluice and securely fastened to the sills. They should be of a width in all to conform to the total width of the sluice, to avoid expense in transportation and unnecessary delay in placing them. If a tight floor is to be had, half-seasoned plank, not less, under any circumstances, than 1½ inches, should be used. The side planks should be worked in a similar manner to the bottom planks, and should extend to the sills. The side linings should be rather thicker than the side planks, and may be rough plank. Where riffles are inserted they do not reach to the bottom plank; in all other instances they should, to avoid wear on the side planks. The posts are braced every alternate sill by means of 1½-inch plank strip, as shown in Fig. 11.

To avoid wear upon the bottom plank, rough plank

must be nailed over them. This should be hard wood, if possible; beech or maple will be found to wear smooth and uniform, where oak splinters.

The cost of the sluice-box will depend upon the locality, the price of lumber, nails, and labor per diem in that locality, as well as transportation.

The great advantage possessed by sluicing in saving gold is due to the thorough washing the material obtains, but the necessity for the erection of retaining

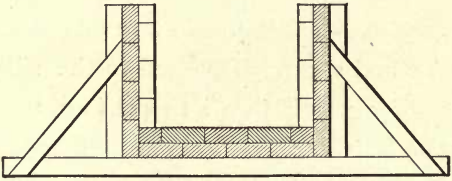

FIG. 11.

dams has in recent years greatly retarded the system and consequently the yearly output.

Wherever, therefore, dumping-ground for sluicing cannot be had, power-washers, steam-dredgers, or hydraulic elevators are resorted to, which are necessarily slower and more expensive in one sense. A log washer, as illustrated in Fig. 11, will perform excellent work and wash 175 cubic yards of material in a day of 10 hours.

Unless a small sluice leads the ore to the washer, a

series of two washers will be required. The blades of the washer agitate the material, thus disintegrating artificially in about the same time as the water-movement in the sluice accomplishes disintegration.

These washers may employ the same water over again, in case the placer mines are worked by drifting and water is scarce; or, if necessary, it may be caught in sumps and pumped to a reservoir for "hydraulicking" a second time. In such instances the coarser

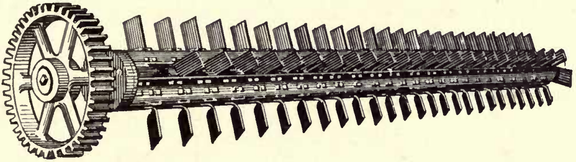

FIG. 12.

material is removed to the dump by scraper-lines or tram-cars, as it is practically dry material.

With such washers screens are indispensable.

These log washers are made as long as 30 feet, generally run double, and are placed on an incline of 1 inch in 1 foot. The material is worked forward by the blades as the washers revolve, thus allowing the ore to be discharged automatically. These log washers are very successful with clay ores and phosphate rock.

Formerly such washers were made of wood with iron blades; these have given place to the steel washer in the cut. The washers discharge into a screen, and thence on to a picking-belt, but such arrangements are not required for hydraulic mining.

CHAPTER IV.

DITCHES AND PIPE-LINES.

THE use of water for "hydraulicking"—that is, breaking down, washing, and transporting material—dates back to 1852, in the early California mining days.

In that year Edward E. Mattison, of Connecticut, with a view to economizing labor, used a stream of water, conveyed to the claim in a rawhide hose to which was attached a wooden nozzle, from which the water spurted against the gravel-bank. This was the first step in hydraulic mining, and was so appreciated that canvas hose bound with wire and rope soon followed, and the nozzle was changed from wood to metal. Up to the present time California has produced the bulk of the gold in this country. It was produced from placer mines, and after the first rich washings, by hydraulic mining, which has been improved in methods and details yearly. Hon. A. S. Hewitt, in his "Century of Mining," says upon the subject: "The position of the auriferous slates and quartz veins, on the west flank of the Sierra, with the precipitous

mountains behind them and the broad plain before, has favored exceptionally the formation of deep auriferous gravels in California, which far exceeds any other known region. And the same topographical features furnish the two other prime requisites of hydraulic mining—namely, an abundant supply of water and a sufficient grade of descent to permit the use of flumes and the escape of tailings." "These advantages the keen-witted miners were quick to appreciate and make available, and I think we may set down the invention of hydraulic mining as an epoch in the progress of American mining." "It has given us an entirely new and original branch of the art, involving many ingenious hydro-dynamic and hydrostatic contrivances; and it has certainly made possible the exploitation of thousands upon thousands of acres of auriferous gravel which could not have been profitably handled in any other other way." "The mountain torrents of the Sierras, caught on their way to the Pacific, have been forced to pause and do the work of man." "The same agencies that buried the gold among the clay and pebbles of the river-beds are now made to strip the covering from it and lay it bare again." "The hydraulic mines produce at present [1876] not less than ten to twelve million dollars annually, and many enterprises which have been prosecuted through years of expensive preparation

are now just beginning to touch their harvests of profit."

"I may mention as an illustration the extensive operations of the North Bloomfield and its two allied companies in California, which have expended in work $3,500,000, and will have six deep tunnels, aggregating over 20,000 feet, and canals supplying 100,000,000 gallons of water daily."*

The graphic literary style of Mr. Hewitt pictures concisely the immense scope hydraulic mining had embraced in 1876. While its application has spread far and wide since that writing, it has in a measure been suspended in California by adverse legislation; lately, however, the matter has been adjusted, in a measure, by the construction of "débris dams," appropriations having been made both by Congress and the State for their construction.

The value of the gravel-bed having been determined, water is sought, and having been found in sufficient quantities, the cost of building flumes and constructing reservoirs and ditches, possibly tunnels and pipe-lines, next demand attention.

The term ditch means an excavation in soil or rock for the purpose of conveying water.

Earthwork is of course preferable to building flumes

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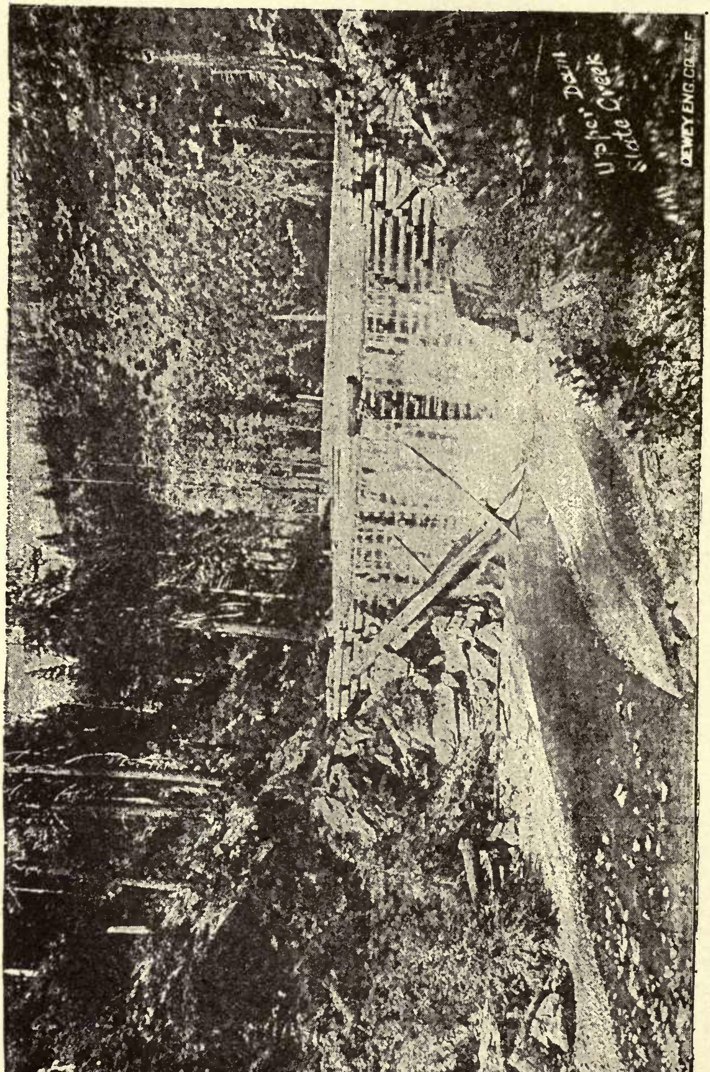
* Transactions A. I. M. E., Vol. V, p. 176.



Debris Dam.

or cutting out a rock channel, and should be employed wherever practicable.

The loose character of the soil may prevent this, even if the bottom and sides of the ditch be puddled, and as it may be of the utmost importance to save water, enough of which is lost from evaporation, such places should have wooden flumes across them. The area of the ditch should conform to the amount of water to be carried, and have a large deep section and slight grade rather than wide, flat, shallow sectional area and a steep grade, for in the first instance the ditch will not be cut so badly by the passage of the water and will not offer the same surface for evaporation and seepage. It is better to carry the ditch around the head of a cañon than to either build a flume on trestles or siphon it through pipes, even if the first cost be more. The ditch should also be provided with waste-gates, through which the water may be discharged, but these gates should be so located as not to undermine the ditch itself.

The proper gradient for a ditch is an 0.25-per-cent grade, or 12.2 feet to the mile; this will insure a free movement of the water and not cause excessive erosion of the banks. If the gradient must be above this, the sides and bottom of the ditch should be examined occasionally.

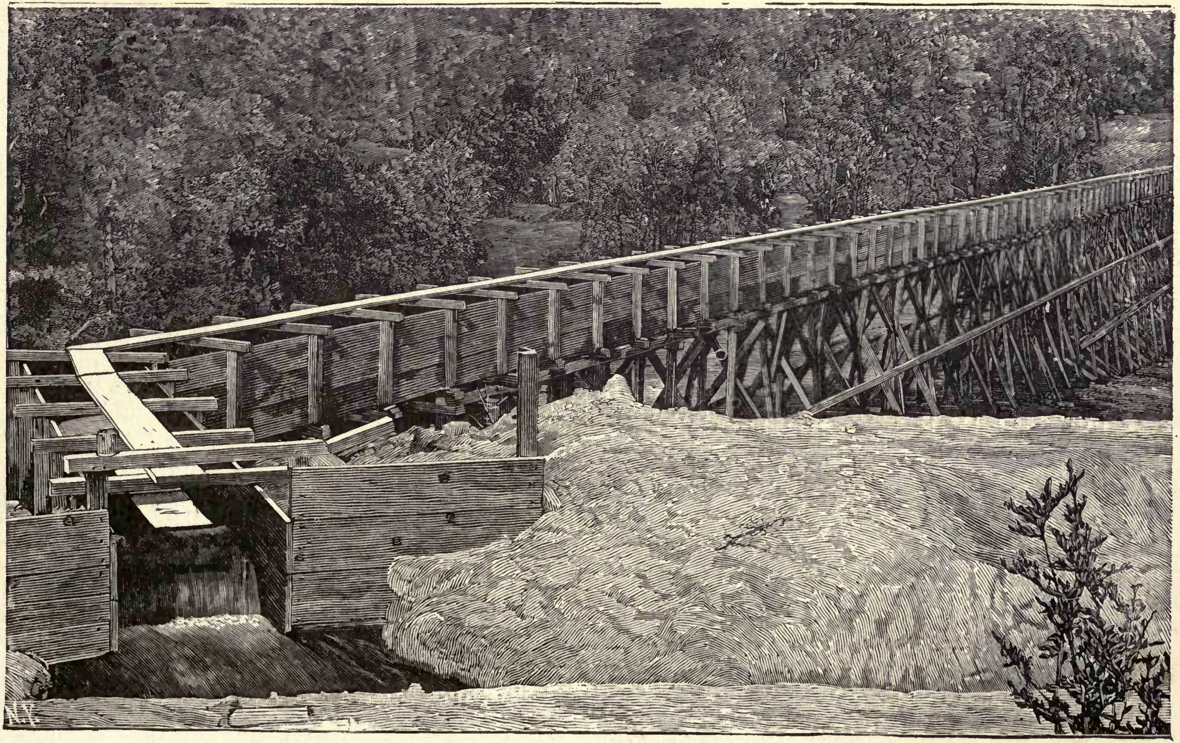
The head of the ditch should not be above the

snow-line, and the grade so made, if possible, to keep the ditch as high as possible above the point where the water is used. Whenever steep drops are encountered flumes or pipes must be used.

The area of a ditch to carry 30,000 gallons of water per minute on 0.25-per-cent grade is $7 \times 5 \times 3.5$ feet: 7 feet across the top; 5 feet across the bottom, and 3.5 feet deep. The cost per mile of such ditch will vary with the nature of the ground and cost of labor.

While it is better, wherever possible, to avoid flumes, there are times when they are not to be avoided. Where rock is to be excavated, or where porous ground is met with, or where chasms are to be crossed, recourse must be had to the box flume.

In building a flume, nothing smaller than $1\frac{1}{2}$-inch plank, tongue and grooved, should be used, and these joints should be white-leaded and well driven home. The sides should be made of the same material, dry pine or spruce—the latter better—and thoroughly fastened to the posts. The sills should not be over four feet apart, and should project 18 inches beyond the outside of the box to take braces, and in cases of tunnels or trestles they should project far enough to receive a 12-inch plank for a walk, in order that the flume may be examined; in other situations the plank placed along the cap-piece will be sufficient. In laying the lining, care should be taken to break



Flume across Gulch.

joints, and the lining should be first-class lumber, free from knots.

The grade given the flume will have some bearing on its size—the steeper the grade the more water the flume will pass for a given area; this will allow considerable decrease in area over the area of the ditch, and consequent economy, wherever the whole grade from the source to the outlet may permit of an increase. The flume-grade may be increased from ditch-grade of 0.29 per cent to 0.50 or 0.75 per cent.

It is not always customary to employ side-braces for the flume; they should, however, be used in certain situations. Wherever the flume crosses a ravine on trestles, braces will make the whole structure more rigid against wind, even when the trestles are anchored by wire ropes; again, on the side of a hill or cliff, where the flume runs full at one time and half full at another, braces will tend in a measure to prevent warping, especially wherever the sun's rays strike the flume.

In this connection it is well to allow a little water to run over the bottom of a flume at all times, to keep the joints tight, as the change from dry to wet condition invariably causes leakage.

The size of a flume will decide the timber to be used in its construction—that is, a flume $2 \times 1\frac{1}{2}$ feet

will not require as heavy lumber as one 3 × 3 feet in sectional area, except for lining.

The sills, posts, and cap-pieces of a flume should not be over four feet from centre to centre, and if three feet between centres it will be more rigid.

In building flumes it is not altogether what they bear in weight, for there are other elements, such as leakage and warping, which must be guarded against, and with sills far apart the latter material elements in the problem have greater play. In the construction of a flume 3 × 3 feet the following timber would be required for 100 feet, the sills, caps, and posts being placed three feet between centres:

34 sills, 3 × 4 × 6′ 11″	=	235 ft. 2 in.
68 posts, 3 × 4 × 3′ 2″	=	215 " 4 "
34 caps, 3 × 4 × 4′ 3″	=	144 " 6 "
68 braces, 3 × 2 × 3′	=	102 " 0 "
54 lining plank, 12 × 1½ × 15′	=	1215 " 0 "
9 " " 12 × 1½ × 10′	=	135 " 0 "
Per hundred feet,		2047 ft. 0 in.
Per mile, 52.8 times,		108,082

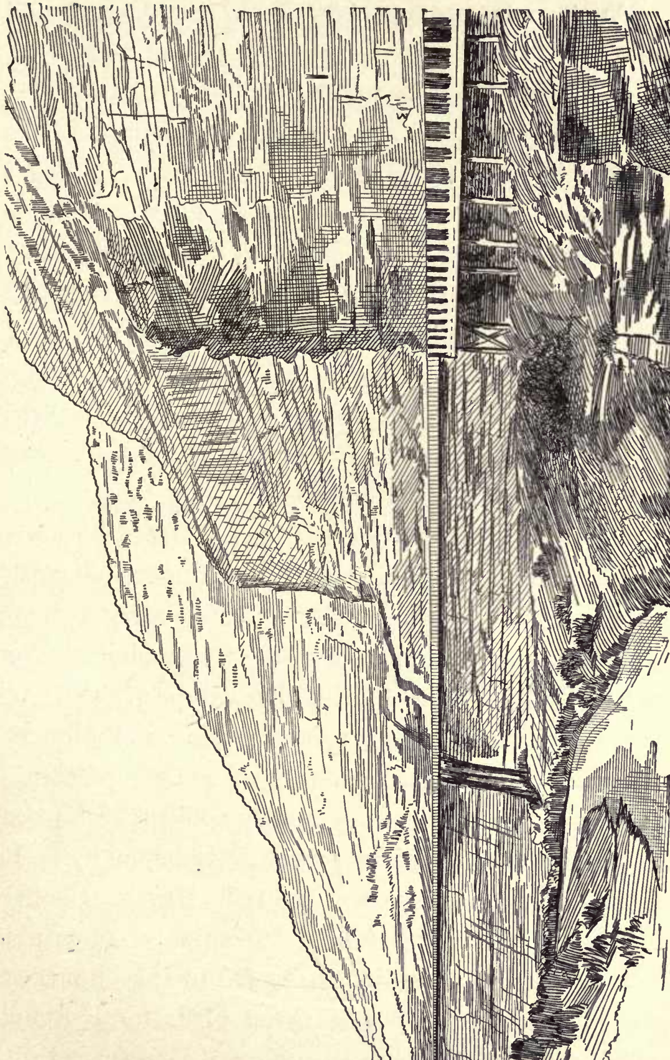
Note.—The above bill does not include walk or battens; add 11,780 feet for 1 × 3″ battens and 19,720 feet for 1½ × 12″ walking-plank per mile.

The lumber per mile of flume does not include

stringers or blocks which must be placed lengthwise of the flume on trestles; in this connection it must be borne in mind that the foundation for a flume must be solid and level, especially under each sill. The usual size for stringers for 3×3 ft. flume is 4×6 inches, but this size must be governed by the distance between bents in the trestle, since the stringers as well tie the trestle bents. With bents 12 feet between centres the stringers should be 4×12 inches for this area of flume.

The sills should be notched for the posts; the caps should be mortised for tenent at the top of the posts and secured by $\frac{1}{2}$-inch wooden pins.

Where curves are necessary in the flume the outer side of the flume must be raised, to correspond to the degree of curvature; $\frac{1}{2}$ inch rise from the lower side for every degree of curvature will be sufficient. This rise should commence on the straight, before it meets the curve, as this will tend to equalize the flow. The rise should be gradual and reach its height at the centre of the curve, and as gradually descend from this point until the flume becomes straight, the object being to change the motion with the least friction possible and avoid the water pouring over the flume at the centre of curve. Wherever curves are met the sills and posts are set closer, and greater care is to be observed in placing the lining.



SIDE HILL FLUME.

At times it becomes necessary to run along the side of a cliff; this is accomplished by drilling holes in the cliff and putting in iron brackets, upon which the stringers for the flume rest. The brackets curve upward parallel to the posts and are fastened by anchors to the cliff above the flume. In San Juan County, Colorado, flumes are carried some distance in this manner beside a cliff. Flumes should have battens over the floor-seams 3×1-inch pine, to prevent wearing at that place, and should be provided with gates at intervals, to allow water to be drawn off; further, where snow or dirt is likely to slide into them from the mountain-side, they should be provided with sheds.

Tunnels are necessities at times. One 5×6 with hand-drills in rock will cost $15 per foot in length; this may be used to conduct water or carry a flume, depending upon the nature of the tunnel-floor. Tunnels are not generally built if they can be avoided; but frequently, to keep the proper grade or shorten the distance, or for other reasons, they are compulsory.

Pipe.—The canvas hose already spoken of for conveying water to the placer was improved upon by R. R. Craig, who used at American Hill, Nevada County, California, about 100 feet of stovepipe. A firm in San Francisco, according to A. J. Bowie, commenced the manufacture of wrought-iron pipes for hydraulic mining in 1856. The great difficulty experienced with

such pipes was the quickness with which they rusted out. They were therefore painted on the outside, but this did not prevent their rusting on the inside.

As pressure became an item of importance, the strength of the pipe was also a consideration, and as cast-iron pipes were costly and difficult to transport, also lapwelded wrought pipe, attention was given to wrought and sheet steel pipe made in lengths suitable for transporting on mules or burros. Spiral-riveted, galvanized pipe was introduced, but this gave way to riveted sheet iron and steel pipe, which is made in sizes from four to sixty inches in diameter, carrying varying pressures up to 600 lbs. per square inch. The general impression prevails that such pipe is not as good either for pressure or permanency, yet the Connecticut Tube Works have been making for municipal service a sheet-iron pipe lined with cement for some years which they claim is more serviceable than cast iron and fully as strong after fifteen years' service.

That it is not necessary to use heavy cast-iron pipe or lapwelded steel or wrought-iron pipe has been proved; and further, that properly constructed sheet-metal pipe, when painted with asphalt inside and out, to prevent corrosion, has lasted twenty-five years and come into more general demand than formerly. The numerous conditions this class of pipe has been subjected to from necessity are such that reliable data

as to pressure, diameter, and thickness of metal have been obtained.

The result of this experience, briefly stated, is, that a comparatively light sheet-metal pipe, in sizes of moderate diameter, when properly proportioned to diameter and pressure, is both cheaper and more satisfactory than other pipe.

Asphalt paint, so long as it is kept intact, makes the pipe practically indestructible so far as ordinary wear is concerned. Where the coating is worn off by abrasion in transportation, or where the pipe is subject to severe shock by the pressure of air * or sudden closing of the gates, or where expansion and contraction open the joints and break the asphalt, corrosion would naturally occur, but this can be remedied by care and an application of paint in such places.

In laying pipe the shortest practicable distance is advisable, wherever the ground will permit it, and sheet pipe should always have a solid foundation along its entire length. If it must cross a small ravine it should be on a trestle and resting its entire length on plank. Short turns or acute angles should be avoided, as they lessen the pressure and give a shock to the pipe; also, the pipe will be more affected by expansion and contraction at such points.

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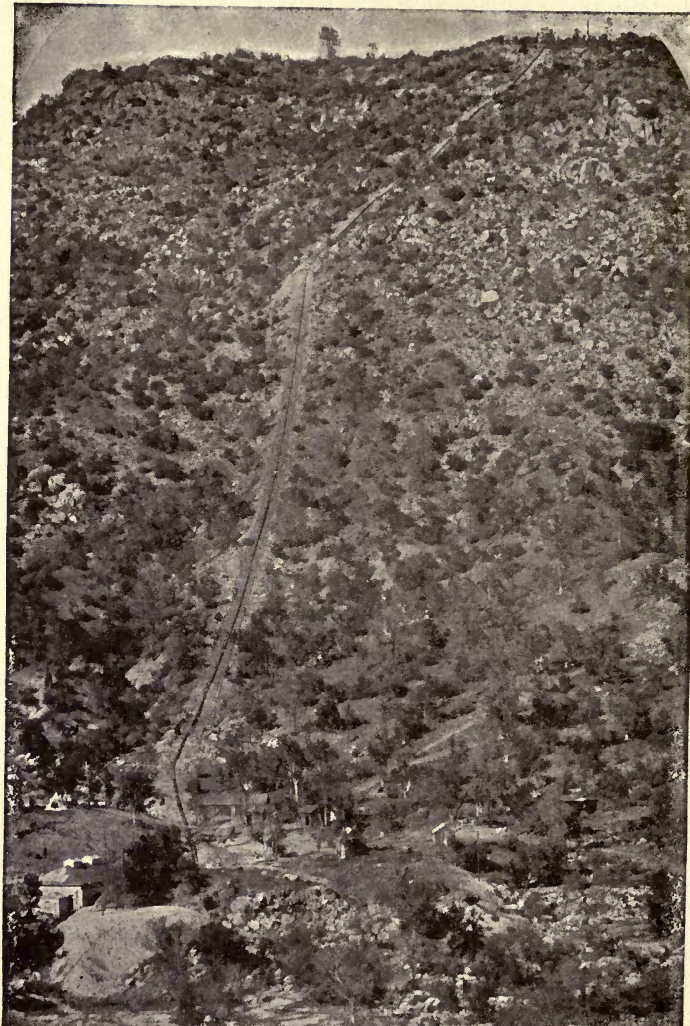
* Water-hammering.

Wherever practicable, the pipe should be laid in a trench and covered with earth, to protect it as much as possible from contraction and expansion or injury. When laid over a rocky surface, straw or rubbish will protect it from the sun, and generally prevent freezing, especially if the water is in motion. As a rule, this pipe is not used along the ditch-line, but runs from the flume or reservoir down a steep incline to the discharge point.

In laying a pipe it should be commenced at the lower or discharge end and worked uphill. In the long-distance transmission plant at Fresno, Cal.,* the construction of the pipe-line commenced at both ends, and considerable difficulty was encountered in closing the gap at the centre of the line. This was due to the alteration in length resulting from the change of temperature. Before sunrise the opening would be 7 feet 8 inches, but in the afternoon the gap would be 7 feet. The connection was finally made before sunrise, and the pipe filled with water before the sun had a chance to expand it.

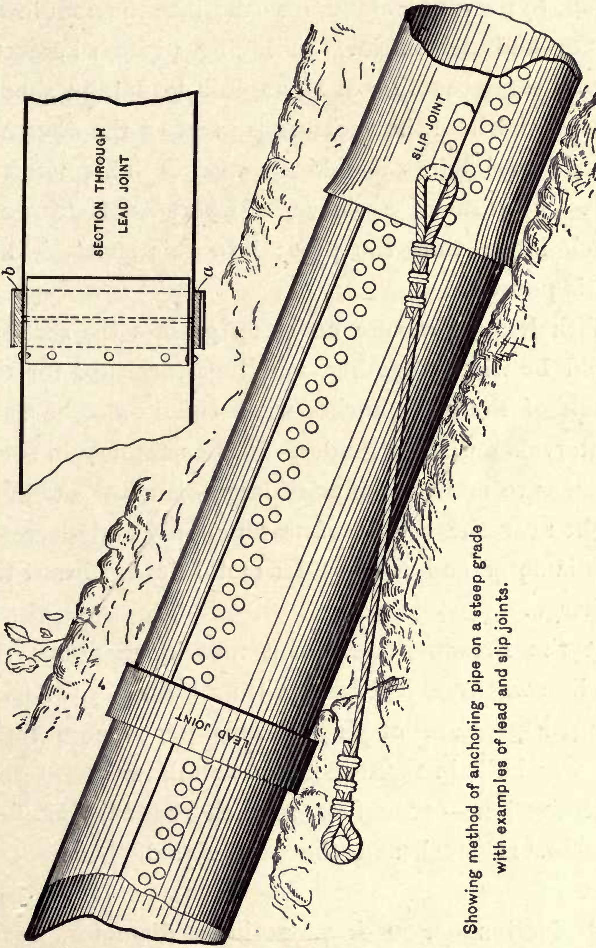
There are two methods of joining pipe-lengths, as shown in the cut Fig. 12. With the slip-joint the pipes are not of large diameter or under very high head; whenever this joint is used, the lower end of

* Scientific American, March 27, 1897.



FRESNO POWER PLANT.

Fig. 14.



Showing method of anchoring pipe on a steep grade
with examples of lead and slip joints.

Fig. 13.

each length of pipe is wrapped with cotton drilling or burlap, to prevent leaking, inserted into the next lower length, and driven in. In laying pipes where the lengths come together at an angle a lead joint should be used, or where the pressure is great or the diameter is large lead joints should be made. This joint is made by means of a sleeve, *a*, which has a diameter $\frac{3}{4}$ inch larger than the pipe; into this space, *b*, hot lead is poured.

With heavy pressure on steep grades, the sections should be wired together, and lugs furnished for the outside of the pipe; anchor-wires should also be used at intervals on heavy grades. It is customary in some instances to make the pipe of large diameter and light weight near the source of water-supply and decrease the diameter and use heavier metal down toward the discharge.

At the Fresno power plant mentioned above the pipe line was 4000 feet long, with a head of 1411 feet, giving a pressure of 609 pounds per square inch. This was built in three sections, as follows:

1st Section.—1820 feet, 24-inch riveted pipe, first half No. 12 steel, and the second half $\frac{1}{4}$-inch steel plate.

2d Section.—400 feet, 20-inch diameter, lock-jointed welded pipe.

3d Section.—1800 feet, 20-inch-diameter lapwelded

$\frac{5}{8}$-inch thick pipe, with flange-joints and rubber packing.

This column of water weighs about 317 tons, and has a thrust of 93 tons, issuing from $1\frac{1}{8}$-inch nozzle at a speed of 9000 feet per minute.

Care should be taken when pipes are covered to test them to see if the joints are tight. In filling the pipes at first all air must be expelled and prevented from being sucked in. Air-valves are necessary where pipes are laid on any but a uniform grade with a heavy pressure.

Care should be taken to see there are no stones or other obstructions in the pipe before being entirely filled for use. Air escaping from the Fresno pipe nozzle makes a noise which can be heard several miles, due to the expansion of air as it leaves the nozzle in bubbles that have been subjected to the heavy pressure. Head in feet is the perpendicular height of the water from its entrance into the pipe to its discharge plus the height of the water above the pipe-mouth at its entrance. Usually the head of water-pressure may be for safe estimate taken at $\frac{1}{2}$ pound for every foot in height; in reality it is 0.434 pounds per square inch for every foot in height.

The loss of head by friction in pipe depends upon the diameter, length, and quantity of water passed.

A series of 88 experiments made by Hamilton

Smith, Jr., as to the flow of water through circular pipes of various diameters from ½ inch to 4 feet are reduced to the formula:

$$v = m\left(\frac{dh'}{l}\right)^{\frac{1}{2}} \text{ where}$$

$v =$ velocity in feet per second,
$d =$ diameter of pipe,
$l =$ length,
$h' =$ effective head,
$m =$ variable coefficients.

The effective head h' was derived from the total head h as follows, c being the coefficient of contraction at entrance:

$$h - h' = \frac{v}{2gc^2}, \text{ in which}$$

$2g$ is the acceleration of gravity due to a body falling, the velocity of water being the same as the velocity of a body falling the same height in a given time in air.

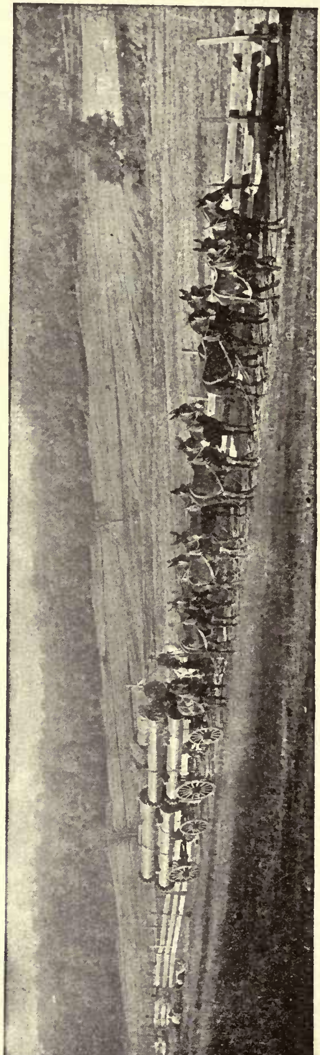
The area of pipe has much to do with the flow of water; by doubling the area we can increase the flow four times under the same head of pressure.

The rubbing surface will increase, but not in proportion to the difference in area. For example, the area of a 1-inch pipe is 0.7854 square inches, of a 2-inch pipe it is four times that, or 3.1416 square inches.

The circumference or frictional rubbing surface of a 1-inch pipe is 3.1416 lineal inches, while the perimeter or rubbing surface of a 2-inch pipe is 6.2832 inches, or twice that of the 1-inch pipe. There are other factors, such as the coefficient of friction, which enter into the problem, which is too intricate for this work; and as life is too short even for the engineer to work out these details, he generally refers to tables, one of which we insert, giving the diameter of pipes and the loss of head due to friction up to 36 inches in diameter. (See table on page 223.)

Pipe-lines generally involve considerable outlay; consequently, calculations as to capacity and strength, as well as spacing and punching, are considerations. The table on page 218 gives the safe head for various sizes of double-riveted pipe up to 42 inches in diameter.

When such pipe is left to the option of the maker the lengths are generally 27 feet. When it is to be transported by wagon the lengths are 20 feet. When the pipe is for heavy pressure and mule-packing it is made in sections of 24 to 30 inches in length, rolled and punched, with rivets furnished to put together on the ground where laid. Pipe of this character can be riveted cold, with the ordinary tools for the purpose, and has a discount of 30 per cent from complete pipe. After riveting, the pipe should be tarred or painted with asphalt and allowed to dry.



TRANSPORTING PIPES FOR THE LINE.

Inverted siphons are used where a valley is too deep to trestle. The water entering the pipe must have a higher head than where it leaves the pipe. At Junction City, Trinity County, California, there has been laid 5700 feet of siphon pipe to get the water over 280 feet of cañon. This is made in two sections; 2200 feet is No. 10 iron 30 inches in diameter, and 3400 feet is No. 7 iron 36 inches in diameter.*

Where slip-joint pipe is to be used an allowance of three inches must be made on each length of pipe ordered, for loss in driving the joints together. In case they leak but slightly, the leak may be stopped by throwing bran or sawdust into the pipe; or if that does not answer, by dry wooden wedges driven into the joints. Should the leak be large, clamps must be used which encircle the joint.

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* Mining and Scientific Press, Nov. 27, 1897.

CHAPTER V.

MINER'S INCH—GIANTS—VALVES—GATES.

ONE gallon of water weighs 8.33 pounds and contains 231 cubic inches.

One cubic foot of water weighs 62.5 pounds and contains 1728 cubic inches, or 7.5 gallons.

The miner's inch is a flow of water equal to 1.5 cubic feet per minute, or 11.25 gallons per minute. The term miner's inch is of Californian origin, and is not known in any other locality, it being a method of measurement adopted by the various ditch companies in selling water to their customers. The term as used in California is indefinite, because all water companies do not use the same head above the aperture, and consequently the miner's inch of water is a variable quantity for each district, no one gauge having been uniformly adopted. The pressure above the water discharge, the size of the apertures through which the water flows, also the plank over which the water flows, and the flume or weir, vary; therefore a miner's inch in one locality may be 10.2 gallons per minute, while

in another it may reach 13 gallons per minute. The most common measurement is through an aperture 2 inches high and whatever length is required, over or through a plank $1\frac{1}{4}$ inches thick, as shown in the illustration, Fig. 15. The lower edge of the aperture

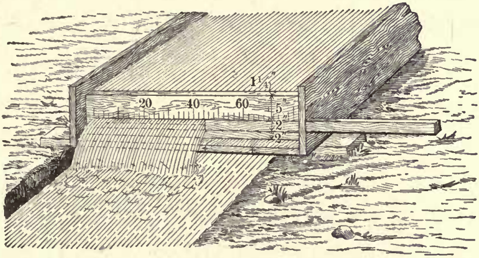

FIG. 15.

is 2 inches above the bottom of the measuring-box, and the top plank 5 inches above the aperture, thus making at the centre of the stream flowing out a 6-inch head of water. Each square inch of this opening represents a miner's inch which will flow $1\frac{1}{2}$ cubic feet, or $11\frac{1}{4}$ gallons of water per minute. If the slide *S* be moved out one inch the aperture for discharge will be 2 square inches and the flow of water 22.5 gallons per minute.

Fraser and Chalmers base their calculations for Pelton water-wheel tables upon the miner's inch given.

Weir Measurement.—Place a board or plank notched, as shown in Fig. 16, at some point in a

stream, where it will dam the water and form a pond above it. The notch in the plank should be twice the depth for small quantities and longer in proportion to the quantity of water to be measured.

The edges of the notch should be bevelled toward the intake side, as shown. The overfall below the notch should not be less than twice its depth; that is, if notch is 6 inches the overfall should be 12. In the

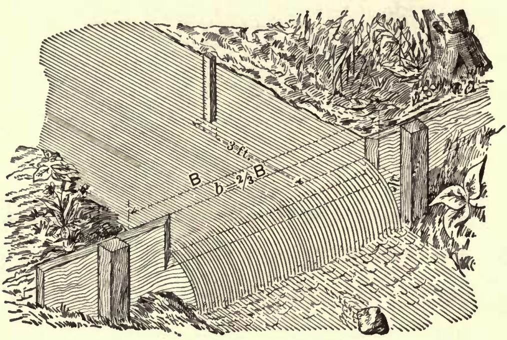

FIG. 16.

pond, about three feet or more above the dam, drive a stake, and then obstruct the water until it rises to the bottom of the notch and mark the stake at this level. Then complete the dam so that all water in stream will the go over the notch, and make another mark at this level on the stake. The distance between the marks on the stake, measured in inches, is the theoretical depth of flow.

To find the discharge over a weir of this description in cubic feet per second :*

Let h = head in inches,

b = the length of the overfall in feet,

c = constant number 3.33,

Q = discharge in cubic feet per minute.

Then

$$Q = \sqrt{h^3} \times b \times 3.33.$$

Example.—How many cubic feet per second will flow over a weir 4 ft. long, 0.64 ft. deep, measured as at h or on the stake, with the constant number 3.33?

$Q = \sqrt{.64 \times .64 \times .64} = \sqrt{.262144} = .512 \times 4 \times 3.33 =$ 6.82 cubic feet per second, or 51.15 gallons per second.

This formula is probably beyond the comprehension of some, and to facilitate matters for the engineer, tables have been made. The table on page 222 gives the cubic feet of water per minute which will flow over a weir 1 inch wide and from $\frac{1}{8}$ to $20\frac{7}{8}$ inches deep. For example, suppose the weir to be 60 inches long (b) and the depth of the water on it to be $6\frac{3}{8}$ inches. Follow down the column marked inches on the left until 6 is reached; follow across the table on the line with 6

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* Trautwine.

until $\frac{3}{8}$ is reached, when 6.44 is found. Multiply this latter number by 60, which gives 386.40, the number of cubic feet passing per minute.

To measure approximately an open stream by velocity of the current and cross section.

Measure the depth of the water at from 6 to 12 points across the stream, at equal distances apart. Add these depths in feet together and divide by the number of measurements made to obtain the average depth of the stream, and this multiplied by its width will give its area of average cross-section.

The velocity of the stream is now found by laying off 100 feet along the bank and throwing a float into the stream a short distance above this mark, timing the float in passing the distance of 100 feet. This should be done several times, and the average velocity determined.

One-half dozen floats thrown into the stream at one time and timed from the first one passing the 100-foot mark to the first one passing the goal will give a closer average time.

Dividing this distance by the average time found for covering it gives the velocity in feet per minute at the surface of the stream. The surface flows faster than the bottom or sides, the difference being about 8 per cent, but for the approximate calculation here

this may not be considered, unless the operator desires it.

The velocity and area having been ascertained, multiply the two together, and the flow in cubic feet per minute of the stream is approximated.

With the introduction of stovepipe in hydraulic mining it was found necessary to retain a short piece of canvas hose to fasten the nozzle of the discharge to the pipe. This gave way as pressure was increased to the gooseneck, a flexible iron joint formed by two elbows working over each other.

The improvement for this arrangement was the radius plate.

The Craig Monitor followed, and then the Fisher Knuckle-joint. Then came Hoskin's Dictator, and Hoskin's Little Giant, which at least has given the nozzles a name, as they are now termed "giants."

The Joshua Hendy Company, San Francisco, make what they term a double ball-bearing giant, while Hoskin's New Hydraulic Giant has various improvements over former styles. These improvements have been gradual, the more recent having increased their efficiency and convenience. The figure given (Fig. 17) is of the Hoskins New Hydraulic Gian

The lever shown on the end is for moving the deflector, which throws the stream to any desired angle without moving the body of the giant. Horizontal

and vertical motions are made with one joint, and this joint protected so as to be durable. The nozzle-butt is attached to the pipe so as to counteract the upward movement when working under great pressure. The pipe is balanced by matching the notch in its flange with a corresponding one in the flange of the elbow. Where there is a downward tendency of the pipe, owing to low water-pressure or small nozzle, use is made of the balancing attachment shown.

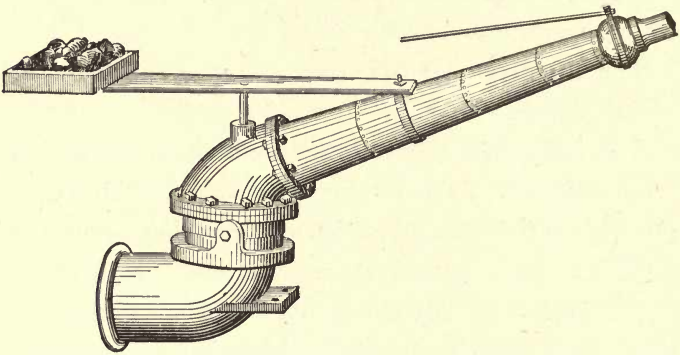


FIG. 17.

The nozzles are from 4 to 9 inches inside diameter, the inlets varying to correspond from 7 to 15 inches diameter.

Rule for finding the spouting velocity from a nozzle of any diameter, under any head or column of water-pressure, and the amount of water which will flow per second through the orifice.

1st. Find the area of the nozzle in square feet.

Area in square feet = diam. × diam. × 0.7854 ÷ 144.

Example.—What is the area in square feet of $1\frac{1}{4}$-inch-diameter nozzle ?

$$1.25 \times 1.25 \times 0.7854 \div 144 = 0.0085.$$

2d. Find the theoretical velocity, and multiply it by 0.80, the coefficient of friction caused by the rushing of water through the nozzle.

Theoretical velocity = $\sqrt{\text{Head in feet}} \times 8.03$.

Actual velocity = Theoretical velocity × 0.80.

Example.—With a head of 25 feet, what is the theoretical and what the actual velocity due to gravity that water will spurt from an orifice?

Theo. vel. $= \sqrt{25} \times 8.03 = 5 \times 8.03 = 40.15$;

Actual vel. $= 40.15 \times 0.8 = 32.12$ feet per second;

$32.12 \times 60 =$ cubic feet per second.

Application to rule.

Question.—What amount of water will flow through a $1\frac{1}{4}$-inch-diameter nozzle under a head of 25 feet?

Rule.—Area in square feet of nozzle, × actual velocity in feet per second:

$0.0085 \times 32.12 = 0.273$ cu. ft. per sec. $\times 7.5 = 2.0475$ gallons per second;

$0.273 \times 60 = 16.38$ cu. ft. per min. $\times 7.5 = 122.85$ gallons per minute.

Practice has demonstrated that one giant with a large nozzle is better than several smaller nozzles in different localities. The large nozzle proportioned to the pressure will do more work, and offers the economic advantages of concentrating the work, thus lessening the expenses. There should be at least two working faces, so that one may be worked while the pipe is being advanced in the other. This is accomplished by running the main line of pipe into the centre of the ground and using a Y which has water-gates in either direction. There should be a gate at the reservoir or flume at the head of the pipe-line to cut the water off. There should also be pressure-indicators and water-regulators which will regulate the flow. The cheapest gate at the head of the pipe-line or along the ditches and flumes where pressure is not excessive is constructed of plank about three feet long and eight inches high, fitted in grooves, one above the other, so they may be easily removed and replaced. The grooves are formed by nailing 2×3-inch plank to the side of the flume; through these guides the gate-plank may be lowered and raised from the top. Considerable trash is at all times moving with the water in the ditches, hence for floating rubbish the flume or pressure-box should have inclined bars of wood or iron to collect it before it goes into the pipe or to the gate. Sand is collected in the

same manner by bars placed across the bottom of the flume over a box, let into the bottom as shown in cut, Fig. 19. The details in the construction of a pres-

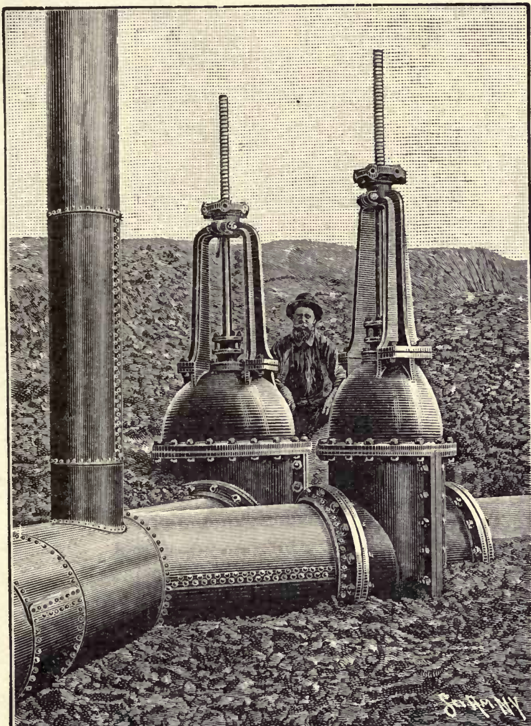


FIG. 18.

sure-box are similar to those of a flume. The screen-bars may be of wood or of iron; if wood, they should be diamond-shaped. As rubbish collects on them

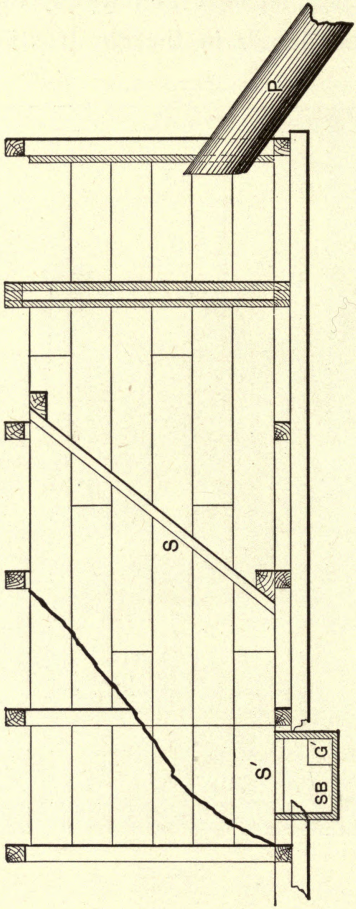


Fig. 19.

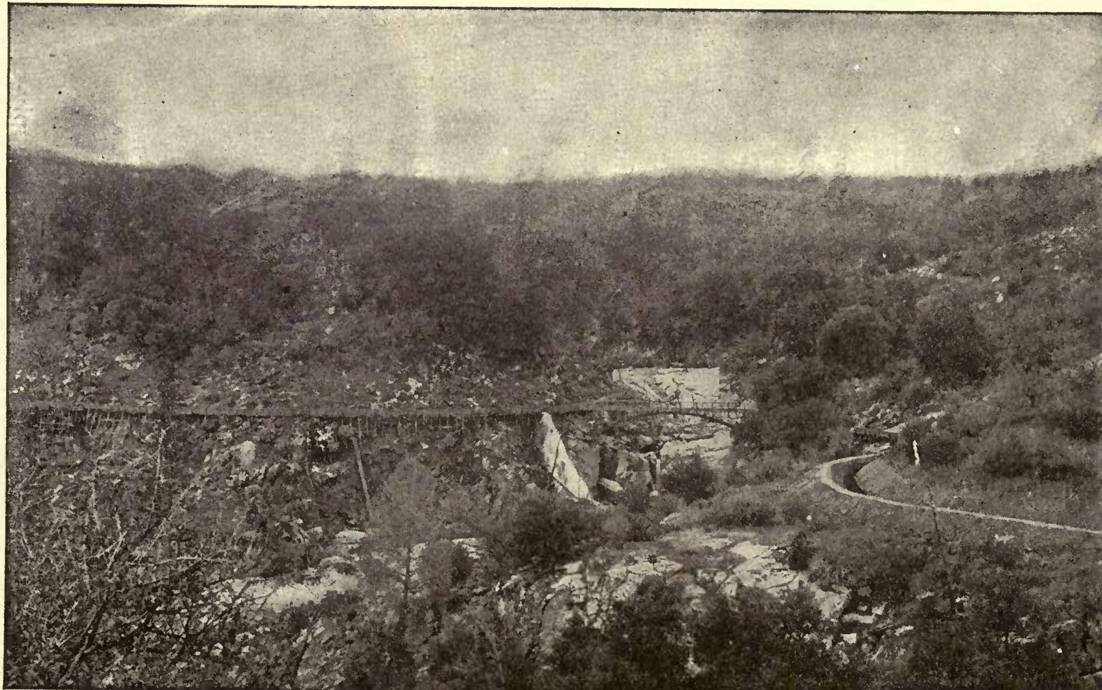
they are cleaned with a rake. The sand-bars *S′* above the sand-box *SB* are of iron, about ½-inch spaces. The box should be about two feet back from the *S* bars, and be provided with a small gate, *G*, to wash out the sand whenever the accumulation reaches near the bars.

The pipe *P* is raised about 2½ inches above the floor, where it is inserted into the end of the box.

The gate *G* regulates the flow of water into pipe *P* and shuts it off entirely if a small waste-gate is placed between it and the pipe. The same construction for gates may be used in dams, flumes, and ditches. Water-gates are expensive when made of metal, but in some instances they will be required in the pipe, near the pressure-box.

Under heavy pressure they are not easy to work, and wear out fast. Pressure-boxes should be and are used for reservoirs which supply the pipe, as well as for flumes. Reservoirs for retaining a supply of water for the pipe are preferable to directing the water from a ditch or flume into it; for if accident should happen to the ditch the work need not stop while it is being repaired.

There are feeders running off from the main ditch to storage reservoirs on most large water companies' lines, for the sake of insuring a supply and to guard against accidents to any part of the main supply-canal



Storage Reservoir.

above them. These are specially necessary where the water-supply is from mountain streams which have a tendency to slack off in water during the summer months. The erection of retaining dams for such reservoirs is part of the ditch system.

The primary object of such dams is to retain water; they therefore should be water-tight. They must have a foundation sufficiently firm to prevent sinking, and a base sufficiently wide to prevent their being moved down-stream by the pressure of the water against them. This base it will be necessary to increase in width as the dam increases in height.

Fig. 20 shows the incorrect mode of building a dam wherever the volume of water is variable. The pres-

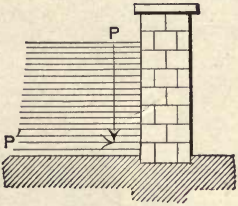


FIG. 20.

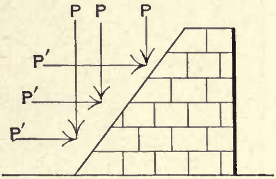
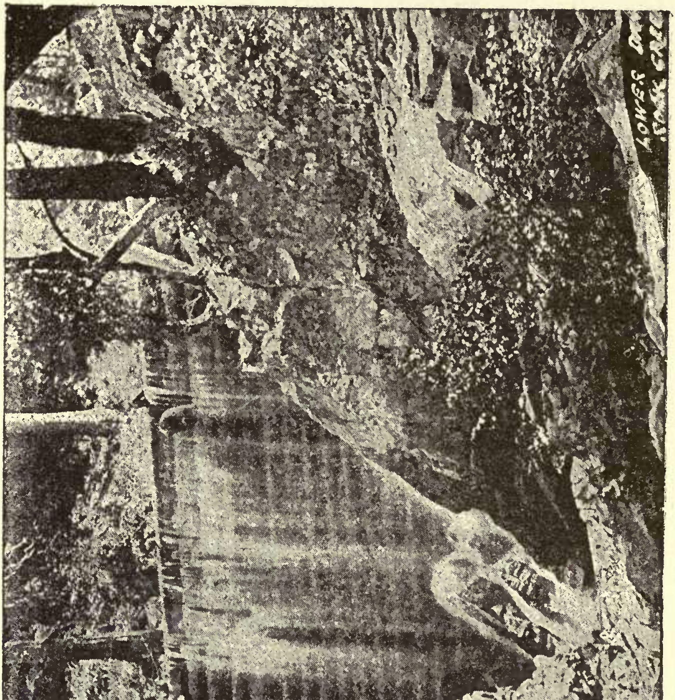


FIG. 21.

sure, *P*, of the water increases with depth, and exerts a pressure, *P′*, which tends to slide the dam off its base. If constructed as in Fig. 21, the dam will be more stable and resist the water-pressure better. For the weight of water, *PPP*, now acts in part to keep the dam in



RETAINING DAM.

position, consequently is opposed to the pressure P' which acts to push the dam outward.

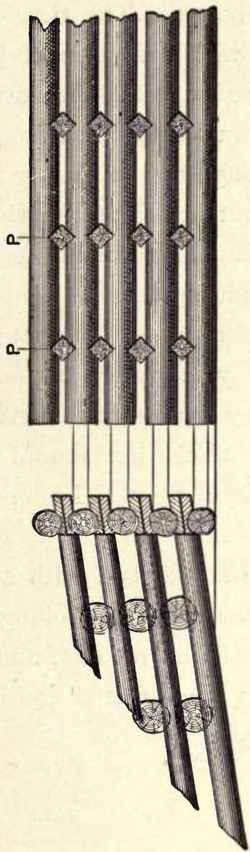


FIG. 23.

FIG. 22.

Masonry dams are expensive, but masonry is necessary at least at the sides of any reservoir which is to

contain any amount of water. The centre may be crib-work, weighted down with stones, puddled clay, etc. The crib is made of logs (Fig. 22), and bolted by spikes, *P* (Fig. 23). The ties, *T*, are notched in diamond-shape, with a section of the log forming a collar. They are longest at the bottom of the crib, to be weighted down; they are also spiked to the log below them through the collar.

The logs are notched to receive the diamond-shaped collar of the ties. The cribbing-logs should have the joints broken, and the ties should not all be one above the other, but should be for about three logs high. This structure may be given a batten on the outside or be reinforced by an embankment of stone. The weighting down of the ties should proceed with the building up. Care should be used to puddle the structure of the dam at its face, to prevent all leakage possible. Large stones laid with some system next the face inside the crib will prolong its life considerably. The ties will not rot fast, and the face will last many years, even when rotted considerably, if such a system be followed.

CHAPTER VI.

GRAVEL-ELEVATORS.

THE Evans gravel-elevator, which is herewith illustrated through the kindness of the Risdon Iron Works Company, is used for treating placer deposits where sufficient fall for tail-sluices is not available, or where it is impossible to run bed-rock sluices. Hydraulic mining, now being under United States Government control, has, as before mentioned, received new impetus in California, where a demand for suitable machinery necessary to overcome obstacles is increasing; consequently, this machine, like the improved dredgers, comes very opportunely.

The principle of the elevator is that of a steam-injector, or where the velocity of the water flowing up through an orifice is sufficient to cause a vacuum and hence a suction through a tail-pipe. It is of course necessary to have a higher head * for such machines than is merely necessary to lift the water to a certain

* About five times the head, over the lift.

height, for friction of the water and the weight and friction of the gravels, together with gravity acting upon the whole mass of water and gravel, must be overcome.

Besides the motive-power pipe, *A*, Fig. 24, there are four other openings in this elevator, *B*,*C*,*D*,*E*. *B* and *C* are termed auxiliary suctions, which allow the water and material to enter at the back of the seat, thus reducing the wear and tear on the machine. The auxiliary suctions can have their tail-pipes extended to any distance beyond the elevator proper, and thus be used for draining in bed-rock, below the sluices connecting with the main elevator opening, *D*. This may be very advantageous at times, and can be carried on without interfering with the main work of sluicing.

The auxiliary openings also increase the efficiency of the elevator, by allowing the proper amount of air and material to enter when the main suction, *D*, becomes choked or for some other cause is unable to do its duty.

This feature economizes water, which must otherwise be turned off or run to waste while the obstruction is being removed or the difficulty obviated.

"These elevators in New Zealand, with less than 400 inches of water (600 cu. ft.), under a head of 225 feet, lifted sand and gravel to a height of 52 feet at the rate of 2400 tons in 24 hours."

Showing Evan's Elevator. I.

"This work was carried on for years, elevating one acre of ground per month, varying in depth from 30 to 35 feet." *

The elevator to accomplish this work used 250 inches, 2812.5 gallons; raised its own water; the water coming from the giant at the rate of 1687.5 gallons per minute, together with the material the giant washed out.

The expenditure of 223 H.P. to accomplish the work of 74.5 H.P., thus obtaining but an efficiency of 33½ per cent of the power expended, does not at first glance seem economical, but when it is considered that 47 per cent of the power is used by the water in raising its own weight and that 19½ per cent is employed in overcoming friction the machine as a pump becomes satisfactory.

In the illustration given

D is the main suction, which takes the gravel and water coming from the giant's washing.

B and *C* are the auxiliary suctions.

E is the discharge end.

A is the supply-pipe for the lifting water, or motive-power pipe.

This particular elevator was connected so as to be permanent; they may be, however, connected so as to

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* Mr. R. S. Moore.

do their own sinking to bed-rock, a commendable feature, when it avoids the necessity of making a sump by hand, which may require timbering and

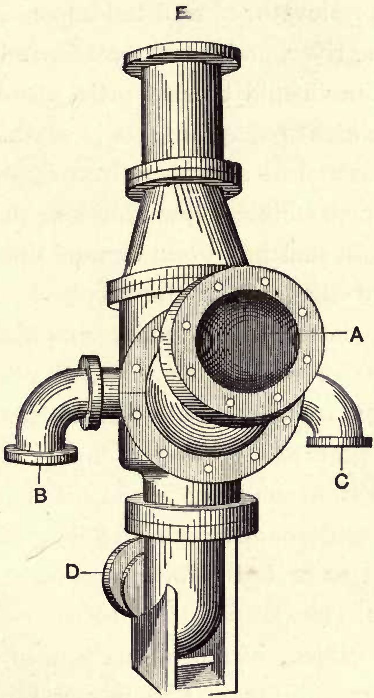


FIG. 24.

pumping arrangements, as well as a diver, to connect the elevator.

The excavation necessary in placing a 16-inch elevator at the Golden Feather Mine, Oroville, Butte

County, Colorado, was 4 square feet, while the previous year an old-style elevator required 128 square feet of excavation and the services of a diver to place it in position.

The Evans elevator was fitted up, lowered to the bottom of the river, and set at work in 12 hours' time.

The machines could be proportioned to elevate all the gravel which one giant could wash and sluice, were the material of a proper size to go through the throat of the machine below *E*. The determination of the area of the throat will depend upon the water available and the size of the stones in the gravel-bank. The latter is an indeterminable quantity, consequently screen-bars or "grizzlies" are placed in the sluice to allow only certain-sized material to pass through into the sluice going to the elevator. Where water is available or lift slight the throat may be proportioned to accommodate large stones: the largest throat on record is for stones which will pass a 9-inch screen.

This is a subject of much significance, for the object of such machines must be in part, if not wholly so, to raise the greatest amount of material possible from the workings and put it out of the way once and for all.

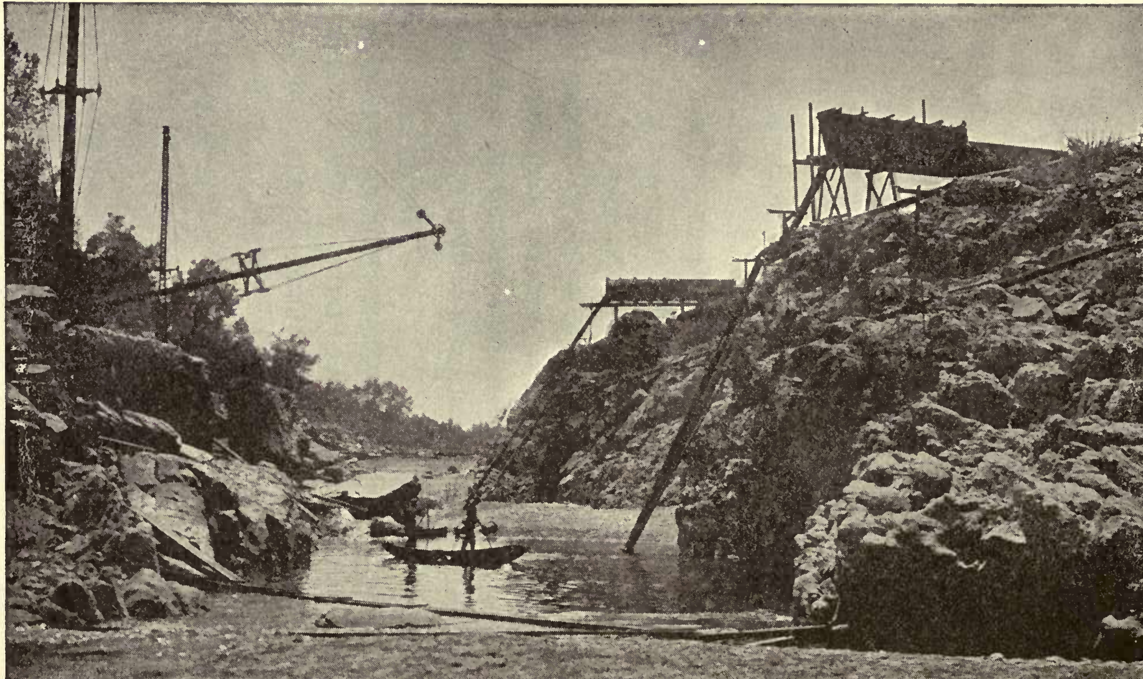
Mining men thoroughly understand the importance

of the preceding clause, and it has been stated to the writer that since the introduction of the Evans elevator mining men are now seeking propositions which require an elevator, although heretofore, owing to heavy cost, weight, and inefficiency of old-style elevators, they would not consider them.

Mines which with former crude machinery were unable to pay expenses have by the use of these new machines been turned into dividend-payers.

There are two instances where these machines have been able to elevate with a $2\frac{3}{4}$-inch jet from the motive-power pipe all the sand, gravel, and water it was possible to bring down the sluice on a 2 per cent grade. The giant had a $2\frac{1}{2}$-inch nozzle, and used 1687.5 gallons of water per minute, while the elevator used 3187.5 gallons of water per minute and raised water and material 52 feet. The highest elevation on record is 70 feet.

The Golden Feather Company, who are very large river operators, dammed the Feather River at Oroville with head and foot dams $1\frac{1}{2}$ miles apart, the object being to work the gravel in the bottom of the river. The river at this place is between two and three hundred feet wide, and from twenty to thirty feet deep; in order, therefore, to reach this gravel-bed dams must be made and the water-course changed, and finally the



Showing Evan's Elevator. II.

water between the dams pumped out. To effect the latter, two Evans elevators were set at work, and accomplished the pumping in $2\frac{1}{2}$ days.* Taking the maker's word for this statement and the lowest estimate for width and depth—viz., $7920 \times 200 \times 20 \times 7.5$—gives 237,600,000 gallons in 60 hours, or 1,980,000 gallons for one elevator per hour.

The data required for estimating the duty for such elevators and which the makers require are:

1st. Quantity of water available. This must include the amount of water the giant will use, and the remainder will only be available for the elevator.

2d. The head of water in feet. By doubling the size of a nozzle under a given head of water there is 4 times the quantity of water passed in a given time, while with 4 times the head but twice the quantity is passed by the same nozzle.

3d. The distance the elevator must lift. Usually but $\frac{1}{5}$ the head can be counted upon, the head being used up in overcoming friction and the power which the weight of the column of water and material of the suction-pipes have in retarding its flow, together with its own weight and friction.

4th. The distance from bed-rock to the top of bank. If placed on the bank the elevator must raise a column

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* Risdon Iron Company.

of water and material equal to the distance between the throat and the level of the water. On the other hand, if on bed-rock, the weight of water and material will assist the elevator.

5th. The largest size of gravel to be elevated.

CHAPTER VII.

EXPLOITING.

HYDRAULICKING is feasible only by two methods, both of which depend upon sluicing; one with a natural, the other with an artificial grade. The methods of mining with the giant and the ground sluicing are similar until that point is reached where the grade is not sufficient to dispose of the débris, and here elevators must be resorted to, in order to get it out of the way. The former is termed a sluicing proposition, the latter an elevator proposition.

Exploiting is commenced by driving a tunnel to reach the gold-bearing deposit when it rests in a channel having rocky sides. This bed-rock tunnel is not always a necessity, and is only used where deep rocky troughs have been made by the ancient rivers. Where tunnels of this kind are to be run a shaft is first sunk some distance from the location of the mouth of the tunnel, in order to determine the level upon which it is to be carried in; otherwise it may be driven too high or too low. If too high, it is useless,

but if too low, a shaft may be driven up to connect it with the washing-pit. Through this shaft the material is dropped to the tunnel, and so conveyed to the sluice, usually just below its mouth. These tunnels are adapted in size and grade to the amount of material to be passed through them. The floor of the tunnel must be paved with cobblestones or blocks, to keep the material from wearing its natural floor away. The ground-sluice is more common, since the older river-beds are not as frequent as the more recent streams, which, as they became filled up, changed their course. The ground or bed-rock sluices are trenches carried toward the work as it recedes, and are the reservoirs for collecting the material as it is washed out and also conveying it to the sluices. At times they are quite deep and expensive to make, but are preferable to tunnels, being open cuts.

The gravel-banks may at times be quite deep, so that it becomes advisable, above 200 feet, to wash them down in two benches. Where such is the case, care must be exercised to avoid the whole bank becoming wet, so as to slide down into the trench or on to the pipes and giant. To avoid this a channel should lead the dirt from the upper bench, with the water in as direct a line as possible to the ground-sluice. Where the bed-rock is not highly inclined, this need not be done with as much watchfulness.

There is considerable danger of the ground caving and covering up the pipes and men, and to avoid this the ground is caved purposely, usually in the daytime, so that the night shift may run it off. To advance the work in the shape of a horseshoe is not advisable, on account of the liability of either one side or the other sliding into the trench and doing damage; for this reason the work should be advanced square and the corners caved as the material is washed down. The sluices being completed, the water-supply assured at least for a season, the water is turned on and washing commenced at the head of the sluice. The dirt as it is taken up by the water in suspension adds to the density of the liquid, and hence to its transporting capacity. This may be better understood by considering the momentum exerted by water moving at a given velocity in feet per second. One cubic foot of water will weigh 62.5 pounds, and if it move at the rate of 10 feet per second, will have a momentum of 625 pounds. The weight of a cubic foot of wet sand is twice that of water, 125.0 pounds. Supposing 1 cubic foot of material and water passing along the sluice to be composed of two-thirds water and one-third sand, the weight would be 82.6 pounds, and the momentum at the above velocity 826 pounds, thus increasing the transporting capacity of the water one-third. The density of the water having been

increased one-third, its ability to float material has been increased one-third; or, expressed in momentum (as far as the rock in the sluice is concerned, whose specific gravity relative to the fluid, is decreased one-third as compared with water), 1101 pounds. The transporting capacity of such a combination is therefore nearly double that of water alone, hence the coarse and heavy material moves along, not on the bottom of the sluice, but above the bottom and below the water. These rocks, further, aid in their movement to disintegrate and wash out the gold from the dirt, and prevent packing of sand by their disturbing action. Heavy rocks will not have the same velocity as lighter, but their colliding has a grinding effect upon the material containing the gold. The grade of such sluices must depend upon the amount of water, and this must regulate their size as well. There are no experiments of such a character as to make a rule by which these gradients being known the transporting capacity can be determined. According to Le Conte, "If the surface of running water be constant, the force of running water varies as the square of its velocity, the transporting power of a current as the sixth power of the velocity." * Friction increases as the square of the velocity and as the

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* Elements of Geology, pp. 19, 20.

cube of the density; however, each liquid will vary, even at times in the same sluice, to a wide degree. Le Conte says: "The transporting power of water will be between the square and sixth power of its velocity." According to Smeaton,* a velocity of 8 miles an hour will not derange quarry rubble stones, not exceeding half a cubic foot, deposited around piers, except by washing the soil from under them. There is no doubt but that the transporting power of liquid in a sluice is greater than in a river-channel, with unequal grades and bed, consequent eddies, etc.; assuming, therefore, that the sluice is 5×3, with a wet perimeter of 5×2, and the velocity 8 miles per hour, or 11.73 feet per second. The fall in every foot-length

$$= \frac{\text{vel.}^2 \times \text{wet perimeter} \times .0001114}{\text{area of waterway in feet}}$$

$$+ \frac{\text{vel.} \times \text{wet perimeter} \times .00002426}{\text{area of waterway in feet}}$$

$$= \frac{11.73 \times 11.73 \times 9 \times .0001114}{10} = .013795,$$

and

$$\frac{11.73 \times 9 \times .00002426}{10} = \frac{.002561}{10} = .000256,$$

$.013795 + .000256 = .014051$ grade, or 1.45 per

* Trautwine, p. 563. 1876 edition.

cent. Practice has demonstrated that the best grade for sluices is about 3 to 4.5 per cent, which would then, with 4.5 per cent grade, acquire a velocity of 24.8 miles per hour. The respective grades are 74.18 and 237.6 feet per mile; friction, however, increases as the square of the velocities, or if x = friction,

$$8^2 : 24.8^2 = x \quad \text{or} \quad x^2 = 3.1 \quad \therefore x = \sqrt{3.1},$$

or 1.761 increase in velocity—that is, 14 miles per hour, instead of 24.8. A sluice 5×2 with such velocity (14) would discharge 12,320 cubic feet per minute.

The size of a sluice depending upon the grade and character of the gravel, also depends upon the water used and its duty. The duty varies. From the large amount of data received and tabulated by Mr. Bowie there is nothing absolute which can be placed as a rule. According to the State of California's engineer, Mr. Hall, 3.6 cubic yards of dirt were moved by 1.5 cubic feet of water, for 24 hours' duration; this is equivalent to 2160 cubic feet of water to move 97 cubic feet of gravel, or 22 cubic feet of water to move 1 cubic foot of material. A. J. Bowie has tabulated 18 cubic feet of water to move 1 cubic foot of gravel at North Bloomfield, and 56 cubic feet of water to move 1 cubic foot of gravel at La Grange mines. In the former instance the grade

was 8 per cent and the gravel light; in the latter the grade was 2 per cent and the gravel the run of the bank. In the former the sluices were 6 feet wide by 32 inches deep; in the latter they were 4 feet wide and 30 inches deep. The height of the banks also varied from 100 to 265 feet at North Bloomfield, against 10 to 80 at La Grange, which would exert considerable influence upon the quantity of material the water could come in contact with, and therefore mine.

Washing is commenced at the upper end of the sluice and continued for half a day or so to allow the sluices to become normal. Care is necessary when bed-rock tunnels are used not to choke the shaft, as time is lost and it is dangerous work to break the jam, possibly requir.ng the use of dynamite.

In case mercury is to be used as an assistance in catching the fine gold, it is poured into the sluice at each riffle, the greatest amounts at the upper end of the sluice and in the first undercurrent, diminishing the amount toward the tail-sluice. The action of mercury is not to absorb gold and form amalgam at once, but to gradually dissolve it; therefore, float-gold, and what is termed rusty gold, is on account of its lightness in the first instance and its coating of some character in the other not so easily caught by mercury. The specific gravity of mercury being at 60° Fahr. 13.58, and native gold 19.3, or if containing

silver 15.6 to 19.3, it follows that the gold will sink into the mercury-bath, while sand, with a specific gravity of 2.63 to 3, will not. But mercury is not necessary to catch the heavier particles of gold, which would lodge anyway, but is useful in saving the finer gold, if it can be held in contact with the mercury a sufficient time to allow it to be dissolved. Riffles are not always able to accomplish this; hence the use of undercurrents, which spread the pulp out thin.

After the formation of amalgam, which is brittle compared with mercury, according to the amount of material it has absorbed, there is danger of loss by its floating away, and this means a loss of mercury and gold.

To avoid this, "clean-ups," or a collection of the mercury, gold, and amalgam, should take place as frequently as possible.

The cleaning-up process may take place in sections or the entire length of the sluice, commencing by washing out the bed-rock tunnel or the ground-sluice with water, taking up their pavements, then washing the blocks and floor down to the first riffle. At this latter point all amalgam and gold washed down is taken up with an iron scoop. The next section of sluice-floor is now removed and treated the same way, until that portion of the sluice to be cleaned up has been gone over. The little water which was used to

wash the blocks is now turned off, and the cleaning of the cracks and nail-holes, termed "crevicing," is commenced by using silver spoons, to which the mercury and amalgam cling. This process having been gone through, the blocks are put back into the sluice and gravel-washing commenced once more. The time occupied in cleaning up will depend upon the number of men put at it. Within 200 feet of the head of the sluice probably three-fourths of all the gold will be found; but smaller quantities will be found nearly to the tail-sluice, or say 1800 feet, depending upon the character of the dirt washed and the nature of the gold. The tail-sluices are cleaned up only at the end of the season. The amalgam collected is now retorted; the quicksilver distilled off is collected again for use by condensation.

Certain quantities of quicksilver will be lost in the sluices and in distillation. In the first instance the loss will be directly proportional to the quantity of water used and material washed, the grades being the same. If clean-ups occur within reasonable periods the length of the sluices will not be a factor; but otherwise it must be, in catching fouled mercury or amalgam particles. There is no method of determining the actual loss of gold, because there is no way of arriving at the absolute amount of gold in the deposit;

it is, however, a certain percentage of the gold content.

The elevator proposition is one where the natural grade is not sufficient to allow sluicing and depositing of the débris into a suitable location. They require more water than simple sluicing propositions. The elevators may be placed in the bed-rock sluice or near the bed-rock tunnel, if necessary, or at some distance away, to answer as tail-sluices. They are to raise the débris from a lower to a higher level and discharge into sluice-boxes. The giant is used for washing down the material as in the former case. Thus the exploiting is every way the same except in elevating. The methods of mining and prospecting the placers of the Klondike is similar to that practised in Siberia.

The work is divided into two sections:

1st. The prospecting.

2d. The exploiting.

To determine the value of the ground, which is frozen to bed-rock the year through, it is necessary to sink shafts. To accomplish this, fires are built on the surface, generally two, one always burning. These fires, 7×7, will thaw to about a depth of 8 inches, and this thawed portion is removed with pick and shovel, after which another fire is built, and so on.

The shaft is continued down until a pay-streak or bed-rock is reached. In order to ascertain in which

direction and how wide the pay-streak may extend, a series of shafts are necessary in the river-bed. It may be possible that the shafts are sunk in barren ground, when a few hundred feet up or down the river may be rich in gold. Prospecting can only be done in the late fall and winter, when the ground is frozen, as the placers are moss first, then gravel and ice, which makes it impossible to keep up a shaft, even if timbered closely, in summer, when melting takes place.

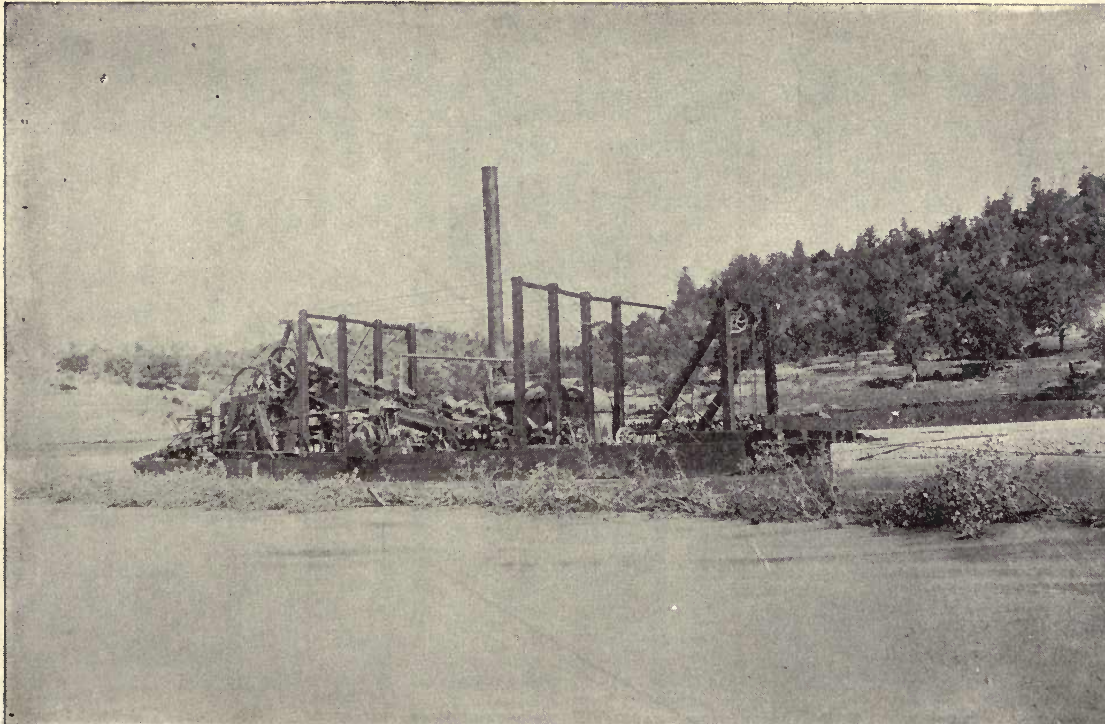
This method of prospecting entails the hardest kind of work and many difficulties not experienced in other warmer localities.

To exploit, work must commence the year after prospecting, and in the winter-time. This makes it necessary to have two drifts underground, each connected with a shaft. The breasts are usually 30 or 40 feet long, with fires built in such a way that the heat will thaw in about 6 or 8 inches along them. The fires are banked so that the heat of the burning wood at the far end of the breast will move toward the shaft and up, while the air descending will pass over the bank or brattice and reach the fire at the far end of the breast.

It is the usual custom to have two working shafts and breasts unconnected, so that while one breast is thawing the other breast may be worked. The material which is thawed and broken down is now

removed to the shaft and stacked on the surface until summer-time, when washing can take place.

The accumulation of gold-bearing dirt is sluiced in summer, if fall enough can be had, or else it is panned: washed by the rocker or "long tom."



River Dredging.

CHAPTER VIII.

DREDGING.

RIVER-DREDGING has been within the last three years brought to such a degree of perfection as to place it among the new gold-recovery processes.

New Zealand is the original home of the successful dredge, where it has been operated since 1886. On the Molyneux River, in New Zealand, there are sixty dredges in operation, the evolution of the present type being brought about by experience, dealing with scientific facts and the causes for past failures. The river-bars gave indications of gold, and being at times rich, it was known that the river-bottom must contain gold in paying quantities. The miners of the earlier days could work the shores of the river with spoons, which consisted of a bag laced or riveted around an iron frame and secured at the end of a long pole, so adjusted and weighted that it could be drawn along the bottom. When filled, or partly so, it was hauled up. Boats were next used with this spoon, and an auxiliary boat contained a rocker for separating the

gold from the dirt. This dredging was the forerunner of the present bucket system of elevating.

"The first primitive vessel took the form of a couple of barrels surmounted by a timber platform, on which the dirt was shovelled by a man standing in the water, the dirt afterward being taken on shore and cradled."* "The next dredge evolved was three canoes lashed together by a board platform and secured by ropes to the shore to steady it. It was provided with the spoon already mentioned for excavating. This contrivance was the first pontoon dredge. The next step was to use water-power to work the spoon, and where such power was not available dredging was carried on by spoons being raised by crab-winches worked by hand."

Mr. Ward, in 1870, the inventor of the current spoon-dredge, designed and worked successfully a bucket-and-ladder dredge, the motive power for moving the buckets being obtained from current-wheels. This was followed by hand-power, then steam-power, as practised at the present time.

The difficulties are many yet in the way of successful recovery by dredging, not in the sense that dredging will not pay dividends, but in the sense of saving a larger percentage of the gold. It is stated that

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* Otago *Witness*.

three-fourths of a grain of gold to the ton will pay expenses. Mr. R. H. Postelthwaite claims that "any ground which is not deeper than 60 feet below water-level, or more than 20 feet above, and which does not contain rocks above one ton in weight, can be handled at from 3 to 5 cents per cubic yard."

The banks out of water may be worked by such dredges from the shore in, making their own float-way, or the bank may be stripped by the hydraulic giant and then worked by the dredge, thus making it possible to work the river-banks as well as the river-bottom.

The construction of dredges is of considerable moment, but the arrangements for saving the gold are of more importance. The first item is mechanical, but the latter is scientific to a much greater extent, for it embraces a knowledge of gold as found in rivers and the application of well-known principles derived from the treatment of tailings. For this reason, the hydraulic miner does not know it all, otherwise there would have been less dredging failures in this country; nor yet has he brought about the present system, it having been imported from New Zealand, and the inventions which will be found of most value in the future of such machines will be derived from the experience of metallurgists in their treatment of tailings coupled with the experience of hydraulic miners,

together with an application of well-known mechanical devices used in other classes of mining.

The treatment of tailings will require exacting care, elaborate sluicing arrangements, with a uniform supply of water and material. It is impossible to save fine gold by a narrow sluice a few feet long, which must carry a large stream of water and possibly a cubic yard of material per minute as well; a sluice twice the size and one-half the length will do better service. This any one may recognize at a glance; for a sluice, say 2 × 3, has a rubbing-surface of 7 feet, while a sluice 2 × 6 has a rubbing-surface of 10 feet; consequently, the 2 × 6 sluice can carry twice the amount of material in a given time; however, the object is not to double the capacity—it is to deliver the same amount of material in the same time but allow twice the opportunity for the gold to settle by offering a larger bottom rubbing-surface and less current to carry the gold to the tail-sluice.

Length of a sluice is not nearly as important as width. New contrivances for saving gold on dredges should be submitted to a metallurgist for approval and his decision be final.

Floating dredges were first arranged to raise the auriferous sands from the river-bed by suction. The reasons for their proving failures were long ago known:

First, light sands carry little gold in such situations,

and what gold there is in them is so fine that it is difficult to concentrate or catch it, being known as float-gold; again, the coarser gold being in flakes, moves readily with the sand and is not easily amalgamated.

Second, suction-pumps could not raise the heavy gravel, and the coarse, easily collected gold lies among such gravel.

Elevators of gravel on the chain-bucket system have proved satisfactory almost from the start, because such excavators could bring up large-sized gravel and get to the gold.

Prof. Eggleston * found that the sands of Snake River required from 70 to 100 colors to produce a value of 10 cents, while at the placer mines of California a color was usually valued at 10 cents.

Mr. Braden † shows what pluck can do even with dredges. Placer-mining machines are of three types, for three different purposes:

1st. For river-dredging.

2d. For dry excavation on land, where material is washed with water after excavation.

3d. For dry excavation and dry treatment of material after excavation.

The river-dredge consists of a scow or flat-bottomed boat upon which the machinery rests. The bow end

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* Trans. A. I. M. E., 1889

† *Engineering and Mining Journal*, vol. LXIV, p. 605.

of this scow has two sections which divide it through the centre sufficiently to allow the elevator-buckets to travel. This class of scow is better and more staunch than where the buckets are placed at the end or bow, even though the heavy machinery is placed at the stern. Fig. 25 shows the deck-plan of such dredge, while Fig. 26 shows a longitudinal cross-section with the chain elevators showing in the division of the hull.

The construction of a scow is not a difficult undertaking, but the hull must be proportioned to the weight of machinery and thoroughly braced. The ribs are to be firmly mortised to the sills and pinned with wood. The bottom and sides should be of 4-inch plank, grooved and wedged, the wedge being of ½-inch dry white pine, well leaded before driven home. The width of the wedge or tongue should be 2 inches, one inch going into the groove in each plank. The ribs are reinforced where they mortise into the sill by a bracket or other brace and are tied across their upper ends by caps which answer as floor- or deck-sills. The floor-sills must be braced by upright posts, and where machine rests by king- and queen-posts. The sills should not be more than 6 feet apart and of 4 × 8 stuff. The ribs and caps will correspond, and need not be over 4 × 6 stuff. The machinery of a heavy character should be on the

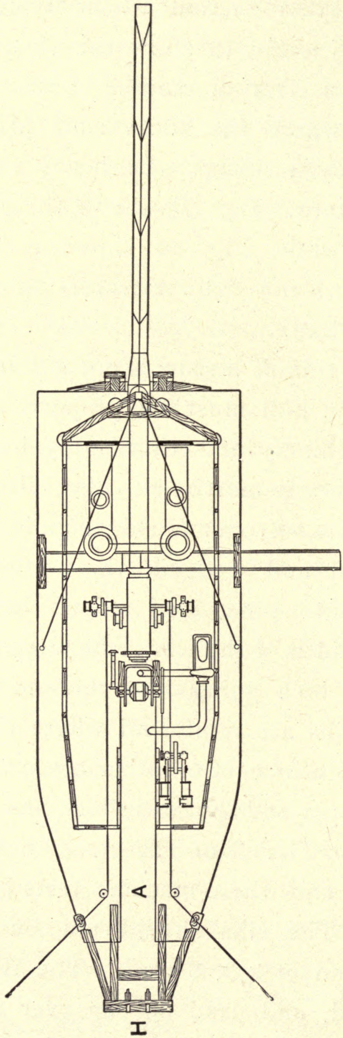

FIG. 25.

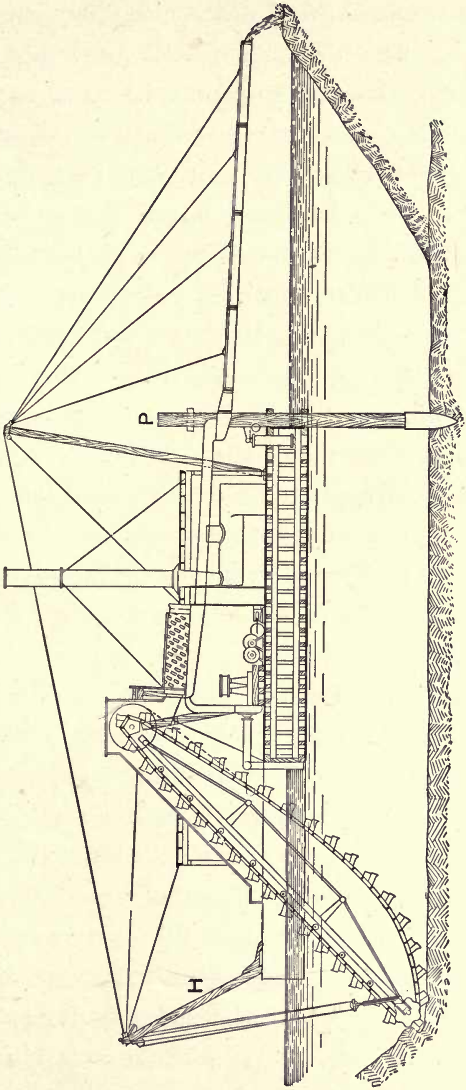

FIG. 26.

sills of the scow, while all other machinery should be above deck. The deck should be water-tight, and the machinery housed, to protect the men and machinery in rainy weather. The illustration shows the dredge to be provided with sharp spiles (spuds), *P*, at one end, to keep the scow up to the current and stationary while at work. Wherever spuds are used they must be driven into the river-bottom, and the scow probably be anchored to the shore by ropes as well. In place of spuds, power-winches with drums are employed, ropes leading from them to the four corners of the scow and thence to the river-bank, or anchors, if the river is too wide. These drums can be worked independently, and thus any position rapidly taken. A fifth line and drum is used to advance the position ahead, so that one man can change the position of the dredge at will.

The machinery for an up-to-date dredge must, besides the engine and boiler, consist of excavators, washers, pumps, sluices, and riffles.

These different classes of apparatus must conform to the character of the gravel deposit and the gold in that deposit. The difficult part of any class of gold-mining is the recovery; from this fact it is evident that possibilities are great for future success, and that this particular branch of the industry is capable of much expansion and development, so as to be an

increasing factor of individual wealth, as it is at present in some instances.

Excavating embraces the removal of a portion of the river-bed containing gold in part up through the water and delivering it to the washer.

Dredging-machines, to be successful, must combine three independent elements, viz.: Excavating, Washing, and Sluicing Apparatus.

These primary machines should have their component parts so arranged as to meet the varying requirements of the material which they are to treat; consequently, the wider range for treatment they possess the more satisfactory they will prove.

Excavating apparatus for river-dredging should combine power and durability, and be capable of handling both fine and coarse material.

The machine which can nearest approximate these conditions is the dipper dredge.

Briefly, there are three types of excavators for river-dredging, each of which, under theoretical conditions, is feasible; consequently, each type has its advocate, but that theoretical suppositions cannot be maintained in river-beds has been amply demonstrated by past failures in river-dredging.

The three classes of excavators in general use are:

The suction pump;

The dipper, and

The chain-and-bucket elevator and excavator.

The suction pump has within its small radius of suction, necessarily close to the suction pipe, sufficient power to raise mud, fine sand, and gravel. This suction power, however, is not able to raise coarse gold, on account of its specific gravity, or the coarse material which usually composes the alluvions close to bed-rock in rivers, and among which the richer gold deposits are found.

The suction pump, when compared with the other two types of elevators, has an exceedingly narrow range of usefulness, even if combined with a rotary cutter on the suction pipe.

The dipper excavator, up to a certain depth, depending upon the length of the dipper-arm, is able to move and remove boulders which the other systems cannot.

This is made possible by the fork on the end of the dipper, the large mouth of the dipper, and the concentration of power. These advantages become more evident when one takes into consideration that they obviate the necessity of raising and lowering the bucket-ladder, backing and filling, with consequent cessation of work during that time, and possibly a change of the scow's position. Further, it is possible to excavate more ground in a given time, closer to bed-rock, and on account of the lateral swing of the

bucket-arm, a wider space without change of the scow's position.

The opponents of the dipper usually advance two arguments: First, that the dipper-door cannot be made tight without great expense for gaskets—and consequently there is apt to be a loss of gold unless they be used.

To obviate this loss from leakage gaskets of common rubber hose are so arranged as not to come in contact with the material during its discharge from the dipper. These gaskets wear well, are not expensive, and can be replaced in ten minutes' time, if necessary.

As the material is brought up in masses, with little water in comparison to the bulk of material raised by the other two classes of excavators, the loss of gold from seepage through the door under any circumstances is slight.

The second objection to the dipper is stated to be the agitation caused by the dipper's attack on the material. This attack is no more vicious than that of a bucket in comparison with their sizes, the water in the dipper being pushed out gradually as the material enters; the ground, therefore, for this objection is tenable only where gold is free and very fine, and in such instances the bucket is likewise objectionable.

The specific gravity of gold is such that particles the

size of pin-heads are not easily floated in swift-running water.

Mr. P. Wright says "that in the Beechwood district of Australia" he found 95 per cent. of the gold within three feet of where it was filled into the sluice, the gold lying on a smooth board, and yet a powerful current failed to move it.

Mr. Alex. J. Bowie says that 80 per cent. of the gold recovered is found within the first 200 feet of the sluice, and quotes an instance where in a 100 days' run which cleaned up \$63,000 $85\frac{7}{10}$ per cent. was caught in the first 150 feet. The grounds taken by some manufacturers of bucket dredgers for their opposition to suction dredgers is that coarse gold is too heavy to be drawn into the tail-pipe, but not too heavy to be disturbed by the dipper.

Careful consideration of the imaginary difficulties attending the use of the dipper which are advanced will probably lead to its adoption, since it has no equal for moderate depths and wide range for handling material.

An objectionable feature of the dipper is the intermittent manner in which it brings gravel to the hopper; at times it delivers a full dipper, but more frequently a less quantity, with much water. It is difficult to receive material in this way, and generally the dipper will require another scow to treat the

material, otherwise the hopper and sluices must be placed upon the river-bank.

The same objections apply to the clam-shell dredge in a greater degree, for, should a stone prevent the shells from closing tight, the gold would be lost in getting the material to the hopper; besides, the agitation consequent upon the shutting and lowering of the dipper may be sufficient to float gold away from the material being excavated.

The Australian and New Zealand dredges are of the chain-bucket type, which is an economical dredging machine.

The action of the buckets being slow and uniform, no undue agitation is caused in the water and no vicious attack is made upon the bed of the river. The material is picked up slowly, hoisted at the same rate, and delivered in a continuous manner to the washer.

The buckets retain the gold from the gravel-bed to the dump, as they are water-tight and pitched to retain their entire contents.

The buckets, further, being in the centre of the boat, keep it on its centre of gravity, and as the material is brought up in smaller masses, with water in considerable quantities, it is more readily broken and washed, which is especially advantageous where clay is present.

Fig. 27 shows a cross-section of a dredge of this

type. The buckets are made of steel, the shovelling-end being reinforced, so that that portion may be replaced as it wears without discarding the whole bucket. The buckets are firmly secured to the chain by rivets. The Bucyrus Company, of South Milwaukee, Wis., make three sizes of buckets, having capacities of 3, 5, and 7½ cubic feet, which will at

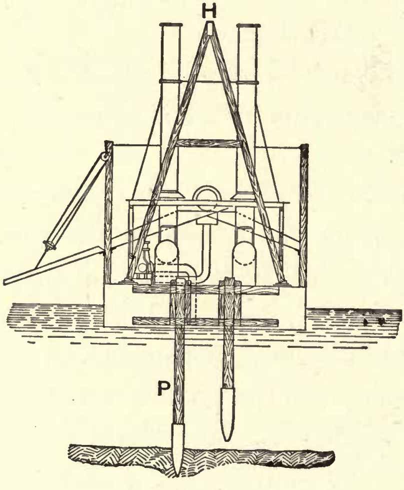

FIG. 27.

a speed of 18 buckets per minute deliver 120, 200, and 300 cubic yards per hour, theoretically; but on account of imperfect filling the practical delivery will be one-half to two-thirds the above amount.

It is claimed for the Robinson patent steel chain, manufactured by the above company, that it has

advantages over all others, inasmuch as the chain-pins are protected and lubricated, so that sand cannot cut out the links and pins, necessitating their frequent renewal.

The chain and buckets are so proportioned that in case an obstruction is met which is immovable their stoppage will stop the engine.

The engine is of ample power to do the work in hard material, but is purposely made the weakest part of the machine, in order to fix the limit of the maximum strains which can occur. If the buckets were running at full speed, with the engine-throttle wide open, at a pressure of 100 pounds steam, nothing but the stoppage of the machinery would occur if the buckets met an obstruction. The depths to which the buckets may work is limited by the power of the engine and length of the bucket-ladder. For deep dredging the boat must be arranged accordingly.

The bucket-ladder is provided with rollers, upon which the chains of the buckets rest as they come from the river-bed loaded with material. The bow of the dredge is provided with a head-frame, to which the bucket-ladder is attached and raised or lowered to meet the requirements of the gravel-bed by differential pulley-blocks and chains. The bucket-ladder has heavy sprocket-wheels at each end to fit the chain, the lower sprocket being moved by the motion of

the chain, the upper one by attachments with the engine.

The buckets empty into a hopper. These hoppers should be constructed so as to catch all material dumped from the buckets; if they do not, an apron should be stretched below the hopper at an incline pitching toward the washer.

Washing.—The buckets having delivered the material to the hopper, it passes from there to a revolving screen. The screen is of sufficient size to pass stones as large as the bucket can bring up—12 to 24 inches' diameter—and of supposed length to thoroughly screen and wash the most difficult material. A series of streams of water are introduced into the interior of the screen to wash the gravel as it is tumbled over and over. The sizes of the openings in the screens vary from 1 to 6 inches, according to the material, so that all material over that size is rejected after being thoroughly washed, and is then discharged overboard on the inclined stone-chute.

This stone-chute is high enough and has sufficient inclination to discharge the material clear of the side of the boat, so that no obstruction can take place on account of the accumulation of tailings. From the under side of the screen, therefore, a discharge of all the fine material takes place, including the gold, together with a considerable quantity of water. This

is carried off and over the stern of the dredge (after a more thorough washing) through a sluice-box of the proper size and inclination and containing a series of riffles, in which the gold is caught.

The sluice-box is extended out over the stern, as shown in Fig. 26, by means of a derrick-pole, and is supposed to be amply sufficient both to carry off the tailings clear of the dredge and to save all the gold.

The screen could probably be improved upon as a washer, but in this instance the clay and smaller material which pass the screen are dropped into a hopper below water-level, from which they are drawn by the suction of a centrifugal pump. This pump runs at a speed which washes the gold and gravel very effectually, at the same time raising it to the sluice-box on the upper deck in a liquid state, from which it passes to the dump, as described. The sluice-boxes are made of steel and fitted with false bottoms of square steel plates. The heavier stones pass over these plates, while the gold and gravel fall between them.

The cost of working gravel by these machines varies from 4½ to 9 cents per cubic yard.

The Postlethwaite dredge (Fig. 23*a*) is built on somewhat different lines from our illustrations. It is of the bucket type, 100 feet long by 23 feet wide. The pulp from the screen is spread out very thin on a

wide table, the object being to save fine flour-gold. The capacity of the dredge is 90 cubic yards per hour, from a depth of 45 feet. The buckets are 3½ cubic feet capacity, and work on a bucket-ladder 67 feet long. The actual horse-power is given at 37, more than half of which is employed in raising 3000 gallons

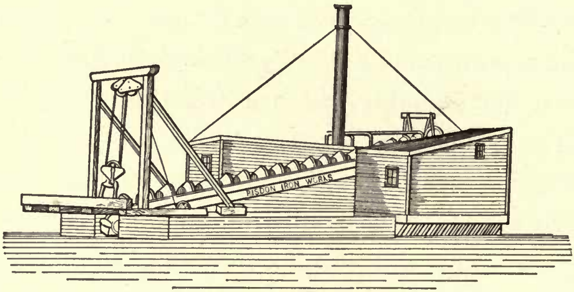

FIG. 28.

of water per minute. The cost of handling material is placed at 3 to 5 cents per cubic yard.

The use of a double screen should wash more thoroughly, and save considerable wear and tear on the pump, also on the sluice-boxes, thereby economizing in weight and first cost.

If the first section of screen pass sizes up to 2 inches diameter, the second section need not pass sizes over ½ inch diameter, to the pump.

The second section could be revolved in a box con-

taining water, and if made of wire cloth would disintegrate clay very quickly. The material which did not pass this screen could be led in a stone-chute over the edge of the boat. Considerable gold could be caught in this box, the remainder of the pulp carried to the centrifugal pump, and thence to the sluice. Experience has demonstrated that the largest portion of the gold is caught in the first 200 feet of a sluice, but considerable is caught beyond that, depending upon the quality of the gravel worked, whether it be clayey or sandy.

Screens are pitched about 1.5 inches to the foot and revolved at the rate of 100 feet per minute; the amount of material to be worked must determine the pitch, but the velocity above mentioned should not be increased, otherwise the stones will hold against the screen or bounce around until they lodge, causing considerable wear and tear, especially if large. The material should not run more than one-third up the sides of the screen; if it does so the screen is revolving too fast. The screen itself should be made sectional, so that it may be replaced where worn without being compelled to cover a whole new side. Boats are at times anchored so that the sluice-boxes will discharge on shore, thus giving them a longer run and a better chance, according to their construction, to save the

gold. The dredge is generally anchored by wire ropes running on shore, if the river be not too wide. These ropes are wound up by capstans (manned or steam-power), fitted to the deck, to move the boat forward or to one side, as excavation progresses.

CHAPTER IX.

TRACTION DREDGES, OR DRY PLACER MINING MACHINES.

TRACTION DREDGES are for exploiting alluvions where little water is available or other existing conditions do not admit of sluicing or the use of hydraulic elevators,

The elements which compose these machines are:

a, The car.

b, The water-supply.

c, The excavator.

d, The washer.

a. The car, with its machinery, will weigh between 40 and 70 tons. The engines should be so arranged as to move the car and machinery forward by gearing. The car must rest firm upon its trucks and have the machinery which rests upon it compact without crowding. It should be so arranged that the centre of grav ity of all machines will fall within the car platform, and thus avoid jackspuds and braces. With this object in view, the plant may be arranged so as to be

supported on four trucks which move on double tracks with 12-foot centres. This arrangement provides sufficient floor-space for the machinery.

The sills of the car are made of steel girders reinforced and stiffened by wooden sills, thus making it very strong and not unnecessarily heavy.

The outfit, consisting of boiler, engines, water-supply pump, washer, and excavator, is mounted upon this one car, and is self-contained.

Such machines, wherever possible, should be gauged to run on 4 feet 8½ inch railroad track; otherwise they must be transported in segments and put together on the ground.

In case they are transported in sections, they may be made wider and have more stable track foundation; some machines of this class having double tracks with 27-inch gauge and 12-foot centres, while others built to be transported on standard-gauge tracks must have jack-arms and side-braces, thoroughly blocked to give them stability. Again, it is not once in a thousand times that a standard-gauge placer-mining machine can be gotten to the diggings without using as much time as is necessary to transport another in sections and place it in running order, even when capable of moving itself over sectional rails.

The tracks for such machines must be kept as near bed-rock as possible, and at the same time the

machinery should be kept level, to prevent undue wear on the journals as well as keep the water in the boiler in proper position. These machines are said to do work on considerable incline, but they are not built for that purpose, and will save money for the operator if kept level. The trouble with the first machines of this dry-placer type was that they cost as much to keep in repair as the value of the gold saved, and as they were discarded, probably more.

b. Mining with dry placer machines will depend upon the water-supply. Beside a river-bank or near some stream they should work satisfactorily; but in situations where water is not abundant they must be economical in its use. If it be required, 85 per cent. of this water may be caught and used over again, thus requiring but 15 per cent. of the total used to be fresh.

The water-supply must in all cases be in quantity from 8 to 10 times the amount of dirt excavated.

Thus, if one cubic yard of dirt be washed per minute, there will be required from 1916 to 2020 gallons of water per minute; of this amount 1629 to 1717 gallons may be used over, thus the actual quantity required to be fresh is from 287 to 303 gallons per minute.

With first-class washers this amount should be reduced at least one-half.

c. The dirt is excavated by an ordinary steam-

shovel, which is capable of handling hard-pan and ordinary hard material. The dipper of the shovel

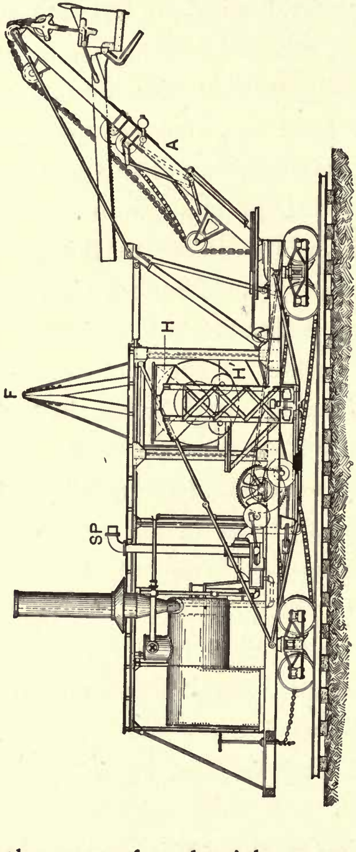

FIG. 29.

works from the arm of a derrick, so arranged in this instance as to have an arm long enough to deliver the material directly over the hopper *H*, Fig. 29. This

derrick with bucket-arm is mounted upon a turntable *T*, which turns by aid of machinery nearly 140° to the hopper.

The excavator being required to raise hard cemented material, must combine strength and power. The boom for the bucket-arm is made to conform to the depth of the alluvions—for example, a 35-foot boom will raise material 18 to 20 feet above the track and make a cut 35 feet in width.

With the exceptions of the length of arm and the turn, the shovel differs very little from the ordinary excavating type. Where the washing-machinery is on trucks at the back or at the side of the shovel, the swing may be half-way round. In some instances the shovel is independent of the washing-machine, which moves with its advance; at times the latter is stationary, the shovel only advancing. Tram-cars are used to haul the material from the shovel to the washer in the latter instance. Dippers of the scoop shape should be used; clam-shells will not answer. Dippers are generally made to hold $1\frac{1}{4}$ cubic yards; when filled the amount will not average over 1 cubic yard. They could probably make six scoops and deliver six buckets into the hopper in five minutes, or 72 cubic yards per hour; but at this rate, under ordinary circumstances, the washer could not handle the material, consequently 1 cubic yard per minute should suffice

for calculations. Where there is plenty of water the shovels can be increased in size up to $2\frac{1}{2}$ cubic yards, but the whole plant must necessarily be increased in proportion.

d. Wherever the hopper for the reception of the excavated material projects beyond the side of the car it must be strongly braced; further, considerable vibration and strain is caused to the structure by the unloading of a cubic yard of material into such hopper at once. Another disadvantage with such hoppers is that they require for gravity fall too much of the height of the machine, necessitating the use of power in raising the waste material to the dump and the pulp to the sluices. To avoid the strain from side hoppers, some makers place the washing and elevating apparatus upon separate cars. It is possible by the use of a wide platform and the double truck system mentioned to raise the washing machinery and allow gravity to dispose of the coarse, medium, and fine material without recourse to elevating machinery for that purpose.

To accomplish this a mill is built upon the car and the hopper placed for the reception of excavated material at the top of the mill and within the centre of gravity of the car.

To raise the material to this hopper a double inclined track is laid from the ground to the top of

the mill. Upon this track two skips run; as the loaded skip ascends the empty skip descends. The power for raising the loaded skip is derived from the engines which work the excavator. The material having been dumped automatically into the hopper, it is washed down over coarse grizzlies or screen-bars.

That portion of the material too coarse to pass the bars goes directly to the dump by gravity; that portion which passes the grizzlies falls into the screen, where it is thoroughly washed of fine material, which falls into the sluices, while that portion too coarse for the sluices moves by gravity to the dump. This system disposes of all tailings and pulp by gravity, thus making an economical and power-saving system, by doing away with elevator engines and one pump, as well as the elevating and conveying apparatus.

The hoppers in dry-placer mining should be so arranged that the material may be washed from pipes surrounding the hopper, and through iron bars forming the floor of the hopper. This will allow the action of the screen to more thoroughly disintegrate the material. The coarse stuff remaining on the bars can be removed by mechanism down over a stone chute. The screen should be of two compartments. The inner compartment, being fed by streams of water which further soften and wash the material, should allow the passage of all stuff up to $\frac{1}{2}$-inch diameter

into the outer-screen compartment. This outer screen should be arranged to move in water, thus further washing and disintegrating material. The pulp from the washing-hopper is drawn off by a centrifugal pump and raised to the sluices containing the riffles, where the gold is caught by them.

The coarse stuff from the inner circle of the revolv-

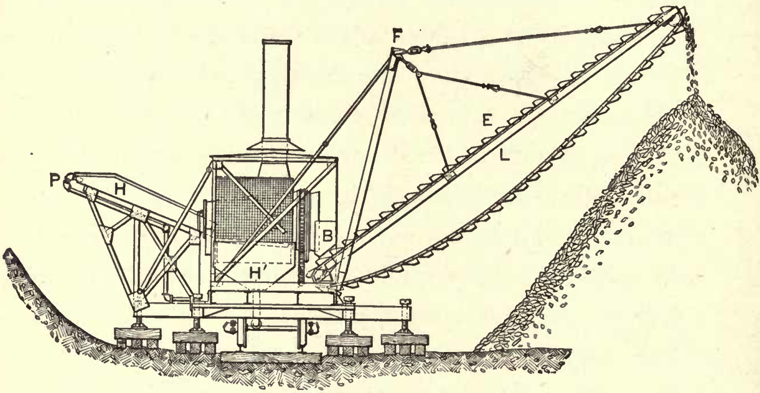

FIG. 30.

ing screen falls into elevators, as at *B*, Fig. 30, and is conveyed by them to the dump.

In the illustration Fig. 30, which is the Traction Dredge of the Bucyrus Company, the hopper is supplied with water from pipe *P*, which washes the material down into the screen; a second hopper, *H'*, receives the washed material containing the gold. The pipe *SP*, Fig. 29, is the pipe for discharging the

pulp into the sluice-box from the pump. *F* is the A-shaped head-frame which supports the bucket-ladder *L*, over which the loaded buckets travel from the screen to the coarse-tailings dump.

The sluice-boxes are not shown. They may be carried a considerable distance in this case at times, but if water be scarce they should be carried where, after the material is discharged, the water may drain into a sump. With plenty of water a one per cent grade will carry off the material in the sluices, which are provided with riffles. The first few sections of sluice-pipe should be of light steel, so that they may be more readily handled and made water-tight.

The Chicago Mining Machine has a complicated screening arrangement, and a short riffle-sluice on the machine itself. The tailings from the riffle-sluice are discharged upon the coarse-tailings dump. This company pays particular attention to washing the material in the revolving screen, which has in its inner compartment a spiral conveyor. No pitch at all is given to the screen, the material being moved forward by the conveyors.

The list of machinery for such dry-placer machines comprises a boiler of the upright or locomotive type, engines to work the shovel and derrick, engines to run the washer and conveying machinery, pumps to supply the water to the washer and sluices.

The horse-power necessary to work the shovel is furnished by a double 8 × 10 inch engine, and may be rated at 25 H.P. To run the elevating and washing machinery 6 × 6 inch double engines are used, which may be rated at 10 H.P. The pumps used are centrifugal, and will require 15 H.P. for their independent engines. At times an auxiliary steam-pump may be required, and in some instances it is part of the system to use it for pumping water to the hopper and washer, leaving the centrifugal pump to work the pulp only. The screens, elevators, sprockets, chains, rollers, etc., will vary in style and make, according to the machine-manufacturers' patterns, and are therefore not described.

With machines rated at 1 cubic yard per minute it is safe to estimate that one hour out of every ten the working of the machine must be stopped for repairs, advancing, or other matters, which will place the average duty at 500 cubic yards per day. The fuel will generally be wood, at $4.50 per cord, and two cords daily, or $9, for 50-H.P. engines; wear and tear, oil and waste, will amount to 3 cents per yard, or $15 per day; labor of 5 men, averaging $3 per day each, $15; making the total expenses of running such a plant, not including quicksilver lost, $40, or 8 cents per cubic yard.

This calculation does not include the superintendent

and his expenses, or transporting the gold-dust. The latter two items will amount to $10 daily at least, bringing the cost to 10 cents per cubic yard.

The amount of gold collected will depend upon the machine construction and the superintendent: a poor machine will not aid a good superintendent. Suppose a machine weighs 50 tons, or 100,000 pounds: the cost at the mine will approximate 7 cents per pound, unless some patents in connection with it raise it considerably higher. Suppose the value of the gravel is 20 cents per cubic yard, and 90 per cent of the value is recovered. The profit under such conditions as named would be $5000 the first year.

What has been said previously regarding the thorough exploration of placer-deposits applies here. The location of the deposit with reference to the nearest railroad station and the condition of the roads leading to it for transporting machinery are matters for consideration; in case it is impossible to transport the boiler, power may possibly be transmitted by electric wires from a distance.

Dry-placer machines, constructed to work without water, cost in wear as much as they save; and it may be set down as an "axiom," that without water they are doomed to failure, unless gold is so plentiful it can be sifted out of the dirt: in the latter instance a coal-sieve will answer.

The dry-placer mining-machines,—those which use water to a limited extent—are built generally by reliable concerns in the steam-shovel business, but several newcomers have lately taken up this work. These companies are not willing to build such machines for placer-work unless they are assured beforehand, by examination and thorough exploration of their own or some other reliable engineer, that the diggings are of sufficient value to make the enterprise a success. The Bucyrus and Marion Steam-shovel companies state this.

From the very nature of placer-mines—that is, the cemented state of the gravel—it follows that if the material can be broken up before it reaches the sluices or the dipper the chances for gold recovery are improved. There are many instances where the ground is so tenacious or the banks so high that it is thought advisable to run in tunnels and counters to break it up with powder.

The writer's experience with breaking down gravel-banks with powder has not been extensive; what it has been, however, has satisfied him that small blasts on the edges of a bank are more economical in the use of powder and more effectual in breaking material fine. For shovel-work, a blast which merely jars the surface and does not throw out the material will be found to be very effectual for working easily in the

dipper, and what is more essential, will wash much easier. The effect of the shot seems to be that of shattering the whole mass without displacement, hence it is very advantageous where water is scarce and steam-shovels are used. If the dipper delivers large lumps of cemented gravel of a tenacious character to the hopper, considerable water must be used to wash it down so fine that it will disintegrate readily; but water in such cases is an item, and consequently any method which will bring the material to the hopper in such shape as to reduce its use for such a purpose to a minimum will help the thorough washing and recovery that much, and further increase the capacity of the machine.

Small blasts are considered to require more powder than large blasts in comparison with the proportion of the ground they disturb. This is true to a certain extent, but the ground is more thoroughly shattered by small blasts than by large ones, and it is the results in detail which we seek; in other words, the quality rather than the quantity for traction-dredgers.

APPENDIX.

THE subject of placer-mines brings up the question, How can they be obtained? If one has to purchase them, the demand will not be great; if one can locate a claim, the subject becomes interesting to the majority of gold-seekers. Information upon this subject, which is well known in the mining States of the West, is entirely unknown in the East, except by those who make a business of mining.

Prior to the Congressional Act of 1866 the ownership of mineral lands was retained by the Government. The agitation for the sale of such lands began in 1850, the object being to make them a source of revenue. The wise policy of leaving such lands open for private development prevailed until 1866, when the uncertainty of titles demanded a change. Possessory rights were all that could be conferred on mining claims, and this could be retained by working and the payment of a small royalty. The law was merely a

license to citizens of the United States to go upon mineral lands of the public. The Government owned the land, but placed no claim of ownership on minerals extracted, except so far as license-fees or royalty was concerned.

The Act of May 10, 1872, allowed any person a citizen, or one who had declared his intentions to become such, and no others, to locate and hold a mining claim 1500 feet long by 600 feet wide, the claim to be by one person, 1500 linear feet along the course of the mineral vein or lode, subject to location; or any association of persons, severally qualified as above, may make joint location of such claim of 1500 feet; but in no event could a location of a vein or lode, made subsequent to the date mentioned, exceed 1500 feet along the course thereof, whatever should be the number of persons in the company. With regard to the extent of surface ground adjoining a lode or vein, and claimed for the convenient working of the same, it is provided that the lateral extent of location, made after May 10, 1872, shall in no case exceed 300 feet on each side of the middle of the vein at the surface, and that no surface rights shall be limited by any mining regulations to less than 25 feet on each side of the middle of the vein at the surface, except where adverse rights, existing on the 10th of May, 1872, may render such limitations necessary; the end lines

of such claims to be in all cases parallel with each other.

Thus it may be seen that no lode claim, located after May 10, 1872, can exceed a parallelogram 1500 by 600 feet, but whether surface ground of that width can be taken depends upon the local or State laws in force in the mining district; but no such laws shall limit a vein or lode claim to less than 1500 feet along its course, nor can surface rights be limited to less than 50 feet in width, unless adverse claims, existing on May 10, 1872, render such lateral limitations necessary. It is provided by the Revised Statutes that miners of each district may make such rules and regulations not in conflict with the laws of the United States, or of the State or Territory in which the districts are situated, governing the location, manner of recording, and amount of work necessary to hold possession of a claim. In order to hold a possessory right to a location made prior to May 10, 1872, not less than \$100 worth of labor must be performed or improvements made thereon within one year from the date of such location, and annually thereafter; in default of which the claim will be subject to relocation by any one else having the necessary qualifications, unless the original locator, his heirs, assigns, or legal representatives have resumed work after such failure and before relocation. The expenditures required

upon such claims may be made from the surface, or in running a tunnel for their development. The Act of February 11, 1875, provided that where a person or company has run a tunnel for the purpose of developing a lode or lodes the money so expended shall be considered as expended on the said lodes, and the owners shall not be required to perform work on the surface to hold the claim. California has recently passed a new local mining law which in some respects is better than the former law, but in others falls short of what is necessary. The two most needed matters in such State laws are:

What shall constitute a proper marking of a claim so as to avoid litigation? The locator of a claim should therefore not neglect his corner pillars, and make them as conspicuous and durable as possible.

The other matter referred to is, What amount of assessment work shall be done to hold claims, and prevent persons from evading the spirit of the United States statute in regard to assessment work? The locator of a claim should familiarize himself with the local laws of the State or Territory in which he lays out his claim; otherwise it may be "jumped," i.e., have some one take it away from him.

Individual proof of citizenship may be made by affidavit: if a company unincorporated, by the agent's affidavit; if a corporation, by filing a copy of the

charter or certificate of incorporation with the Secretary of State, County Recorder, or with the nearest Government Land Officer—possibly better with each.

Locators against whom no adverse rights rested on the date of the Act of 1872 shall have, on compliance with general and recognized custom, the exclusive right to possession and enjoyment of the surface enclosure, and of "all veins, lodes, and ledges which lie under the top or apex of such lines, extended downwards vertically," even though they in their descent extend outside the side lines of such surface locations." (Probably the best expert on the Apex Law is Dr. Rossiter W. Raymond,* of New York City. He is one of the framers of the law of 1875, and because of his being at one time at the head of the U. S. Government Survey, he is considered to be the best-informed man on the subject.) The rights to such outside parts of veins or ledge is confined to all that lies between "vertical planes drawn downward," as described, so continued that these planes "will intersect the exterior parts of the said veins or ledges." The surface of another claim cannot be entered by the locator or possessor of such lode or vein.

The Land Office construes the word *deposit* to be a general term, embracing lodes, ledges, placers, and

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* Law of the Apex. R. W. Raymond. A. I. M. E. Transac-

all other forms in which valuable metals have been discovered. Whatever is recognized as mineral by standard authorities, where the same is found in quality and quantity sufficient to render land sought to be patented more valuable on this account than for the purposes of agriculture, is treated by the Land Office as coming within the meaning of the Act. Lands, therefore, valuable on account of borax, soda carbonate, nitrate of soda, alum, sulphur, petroleum, and asphalt may be patented.

The first section of the Act of 1872 says, "all valuable mineral deposits." The sixth section uses the term "valuable deposits." This latter section required the Supreme Court to rule petroleum a mineral deposit. This session of Congress, December, 1897, was presented with a bill drafted by Mr. A. H. Ricketts, a mining lawyer of San Francisco, the purpose of which was to recover from railroad companies those lands for which they received patents which lands were known to be mineral before the patents were issued, where they have not passed into the hands of innocent purchasers. Such a bill is eminently proper, and would take away from the railroad companies only lands which they ought never to have received, and which the California Miners' Association sought so strenuously to prevent

their obtaining.* "It is said to be the practice of the railroad companies, when they receive patents for lands to which they know they are not entitled, to transfer them to some outside party who claims to be an innocent purchaser." "The miners generally are determined that the railroad companies shall not hold mining property that never was granted by Act of Congress."

The grant of Congress referred to was, that certain railroads, because of their being built, should have each alternate additional section for ten miles back on each side of the roads as completed, but excludes all minerals except iron and coal from the grant. As fast as the lands were surveyed the companies applied for patents.

Prospectors cannot obtain claims on patented lands, and consequently should keep off them. Mr. Ricketts' proposed law defines the word *mineral* to mean "cinnabar, copper, lead, borax, asphalt, petroleum, oil, salt, and sulphur.

Deposits of fire-clay may be patented under the Act of 1872, and so may iron-ore deposits be patented as vein or placer claims. Lands more valuable on account of deposits of limestone, marble, kaolin, and mica than for purposes of agriculture may be patented as mineral lands.

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* *Mining and Scientific Press*, Dec. 18, 1897.

The Act further provides that no lode claim can be recorded until after the discovery of the vein or lode within the limits of the ground claimed. The claimant should therefore, prior to recording his claim, unless he can trace the vein on the surface, sink a shaft, run a tunnel or drift to a sufficient depth therein to discover and develop a mineral-bearing vein, lode, or crevice; should determine, if possible, the general course of such vein in the direction from the point of discovery, in which direction he will be governed in making the boundary of his claim on the surface; and he should give the course and direction as nearly as practicable from the discovery-shaft on the claim to some permanent well-known points or objects, such as, for instance, stone monuments, blazed trees, the confluence of streams, etc., which may be in the immediate vicinity, and will serve to perpetuate and fix the locus of the claim, and render it susceptible of identification from the description thereon given in the record of location in the district. He should drive a post or erect a monument of stones at each corner of his surface ground, and at the point of discovery or discovery-shaft should fix a post, stake, or board, upon which should be the name given the lode, the name of the locator, the number of feet claimed, and in what direction from the point of discovery, it being essential that the location notice be

filed for record. In addition to the foregoing, the description should state whether the entire claim of 1500 feet be taken on one side of the point of discovery or whether it is partly upon the other side, and in the latter case how many feet are claimed upon each side of such discovery-point.

Parties locating lodes are entitled to all the dips, spurs, angles, variations, and ledges of the lode coming within the surface ground.

The following diagram will aid the locator in his work (Fig. 31):

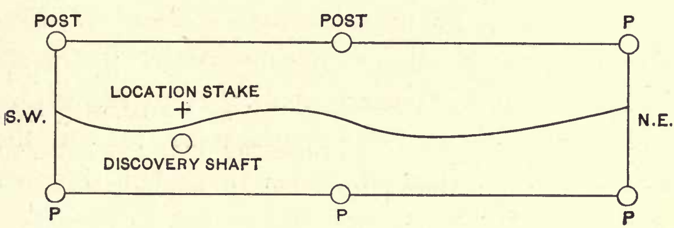

FIG. 31.

MINER'S FORM OF NOTICE.

I, John Doe, hereby give notice that I have this —th day of ———, A.D. 18—, located this, the ——— lode. I claim 1500 feet in and along the vein, linear and horizontal measurement. I claim 1200 feet along the vein running in a northeasterly course from the discovery-shaft, and 300 feet running along the vein in a southwesterly course from the dis-

covery-shaft. I also claim 150 feet on each side of the vein from centre of crevice as surface ground.

JOHN DOE, *Locator*.

In case there are more than two locators, the names of the two should be inserted, and the pronoun "we" where "I" occurs.

There may be intervening claims which will lessen the length or the width of the claim. Within reasonable time after the location shall have been marked on the ground, notice thereof accurately describing the claim in manner aforesaid should be filed for record with the proper recorder of the district, who will thereupon issue the usual certificate of location. District customs are followed in this matter, and should be familiarized by the prospector. These regulations will require that a location certificate be filed with the recorder, in the county in which the lode is situated, within a specified time after its location.

FORM OF RECORDING LOCATION.

STATE OF ——— } *ss.:*
COUNTY OF ——— }

Know all men by these Presents, That I, John Doe, the undersigned, have this —th day of ——— A.D., 18—, located and claimed, and by these presents do locate and claim, by right of discovery and location, in compliance with the Mining Acts of Congress, approved May 19th, A.D. 1872, and all subsequent

Acts, and with local custom, laws, and regulations, ——— feet linear and horizontal measurement, on the ——— lode, along the vein thereof, with all its dips, angles, and variations, together with ——— feet, running ——— from centre of discovery-shaft. Said discovery-shaft being situated upon said lode, and within the lines of said claim ——— Mining District, County of ————, and State of ———, and further described as follows:

Beginning * at the location-stake and running in a line southwesterly 300 feet, thence northwesterly to a post 150 feet.

Beginning at this post and running a line northeasterly 1500 feet, to a point marked by post and pile of stones; hence southeasterly 600 feet to a post placed in the ground and marked II; hence southwesterly 1500 feet to a point marked by post and stone pile; and thence 600 feet northwesterly to the point of beginning.

Said lode was located on the —th day of ———, A.D. 18—.

JOHN DOE.

Attest: ——— ———

—th day of ———, A.D. 18—.

In order to hold possessory rights to a claim of 1500 feet of vein or lode located as aforesaid, the Act requires that until a patent shall have been issued therefor, not less than $100 worth of labor shall have

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* Explanatory only. See Fig. 31.

been expended annually, on the basis adopted by the local mining regulations; in default of which labor or improvements the claim will be subject to relocation by any other party having the necessary qualifications, unless the original locator, his heirs, assigns, or legal representatives have resumed work thereon after such failure and before such relocation.

The importance of attending to these details in the matter of location, labor, and expenditure will be the more readily perceived when it is understood that failure to do so may invalidate the claim. After the patent has been granted, no more assessment work is required.

Five dollars per day is usually allowed for each day of every eight hours' work performed upon a mine for the purpose of holding title or performing the necessary amount of work for the patent, and no other expenses shall be considered as expended for the purpose of holding or protecting title.

PLACER-CLAIMS.

The U. S. law prior to May 10, 1872, allowed each person 160 acres or a quarter section of a square mile of placer-ground, if located. From the above date all placer-claims shall conform as nearly as practicable with the United States system of public surveys, and no such location shall include more than 20

acres for each individual claimant. The provisions of the law are construed by the Commissioner of the General Land Office to mean that after the 9th of July, 1870, no location of placer-claim can exceed 160 acres, whatever may be the number of locators associated together, or whatever the local regulation of the district may allow; and that from and after May 10, 1872, no location made by an individual can exceed 20 acres, and no location made by an association of individuals can exceed 160 acres; which location cannot be made by a less number than eight *bona-fide* locators. But whether as much as 20 acres can be located by an individual, or 160 acres by an association, depends entirely upon the mining regulations in force in the respective districts at the date of location; it being held that such mining regulations are in no way enlarged by the statutes, but remain intact in full force with regard to the size of locations, in so far as they do not permit locations in excess of the limits fixed by Congress. A local regulation is valid which provides that a placer-claim, for instance, shall not exceed 100 feet square. Congress requires no annual expenditures on placer-claims, leaving them subject to the local laws, rules, regulations, and customs of the mining district.

The California Law regarding Placers.—Section 4, Act of 1897, reads:

"The discoverer of placers or other forms of deposit, subject to location and appropriation under mining laws applicable to placers, shall locate his claim in the following manner:

"First. He must immediately post, in a conspicuous place at the point of discovery thereon, a notice or certificate of location thereof, containing:

"*a.* The name of the claim.

"*b.* The name of the locator or locators.

"*c.* The date of discovery and posting of the notice hereinbefore provided for, which shall be considered as the date of location.

"*d.* A description of the claim by reference to legal subdivisions or sections, if the location is made in conformity with the public surveys; otherwise, a description with reference to some natural object or permanent monument as will identify the claim; and where such claim is located by legal subdivisions of the public surveys such location shall, notwithstanding that fact, be marked by the locator upon the ground, the same as other locations.

"Second. Within thirty days from the date of such discovery he must record such notice or certificate of location in the office of the county recorder of the county in which such discovery is made, and so distinctly mark his location on the ground that its boundaries can be readily traced.

"Third. Within sixty days from the date of the discovery the discoverer shall perform labor upon such location or claim in developing same to an amount which shall be equivalent in the aggregate to at least ten dollars' ($10) worth of such labor for each twenty acres, or fractional part thereof, contained in such location or claim.

"Fourth. A failure to perform such labor within said time shall cause all rights under such location to be forfeited, and the discovery thereby shall at once be open to location by qualified locators other than the preceding locators, but shall not in any event be open to location by such preceding locators, and any labor performed by them thereon shall not inure to the benefit of any subsequent locator thereof.

"Fifth. Such locator shall, upon the performance of such labor, file with the recorder of the county an affidavit showing such performance, and generally the nature and kind of work so done."

Section 5 of the same act reads: "The affidavit provided for in the last section, and the aforesaid placer notice or certificate of location when filed for location, shall be deemed and considered as *prima facie* evidence of the facts therein recited. A copy of such certificate, notice, or affidavit, certified by the county recorder, shall be admitted in evidence in all actions or proceedings with the same effect as the original."

In locating a claim, if the above directions are closely followed, no matter what the locality, the prospector will generally have complied with the law. However, it is better to have the local laws well understood whenever possible.

The United States statutes provide "water-rights."

1. That as a condition of sale, in the absence of legislation by Congress, the legislature of a State or Territory may provide rules for working mines, involving easements, drainage, and other necessary conditions; these to be expressed in the patent.

2. All prior rights, arising from possession, in the use cf water, and recognized by local laws, etc., or judicial decisions, shall be regarded as vested, and shall be protected. This right of way is also granted and confirmed. Damages are to accrue if a land-settlers' rights are interfered with.

3. All land patents shall be subject to vested and accrued water-rights, including ditches and reservoirs. Officers of the U. S. Land Office are required to file with the General Land Office the local laws on such matters. Water privileges are, since the Act of May 10, 1872, located in the same manner as mines, subject to local regulations, i.e., by definitely locating the five acres by monuments, and recording with the district or county recorder. If the local rules and decisions of courts make the privilege forfeitable for non-use,

another party may come in and claim the water-right. The Federal courts have decided that the right of way to construct flumes or ditches over public lands is unquestionable. It has also been decided that the miner's right to water, within "reasonable limits," is not to be questioned. "It must be exercised, however, with due regard to the general condition and needs of the community, and cannot vest as an individual monopoly."

MILL-SITES.

Land, non-mineral in character, and not contiguous to the vein or lode, used by the locator and proprietor for mining or milling purposes, can be included in any application for patent, to an extent not to exceed five acres, and subject to examination and payment as fixed for the superficies of the lode. The owner of a quartz-mill or reduction-mill, not a mine owner in connection therewith, may also receive a mill-site patent. Such sites are located under the mining act, and in compliance with local law and customs as recognized. Such possessory rights give title also to all growing timber thereon. There must in every case be given satisfactory proof of the non-mineral character of the site, and the improvements thereon must be equal to $500. A mill passes to a railroad if located on railroad land-grant.

THE MINING REGULATIONS FOR THE CANADIAN YUKON.

We give below, substantially in full, the new regulations governing placer mining and dredging in the provisional district of the Yukon, as approved by Order in Council dated Ottawa, January 18, 1898. These regulations constitute the mining law under which all operations must be conducted in that portion of the Yukon region which is in Canadian territory; and the Dominion Government is making provisions for their strict enforcement. The regulations are as follows:

INTERPRETATION.

"Free Miner" shall mean a male or female over the age of 18, but not under that age, or joint-stock company, named in, and lawfully possessed of, a valid existing free miner's certificate, and no other.

"Legal Post" shall mean a stake standing not less than 4 ft. above the ground and flatted on two sides for at least 1 ft. from the top. Both sides so flatted shall measure at least 4 in. across the face. It shall

also mean any stump or tree cut off and flatted or faced to the above height and size.

"Close Season" shall mean the period of the year during which placer mining is generally suspended. The period to be fixed by the mining recorder in whose district the claim is situated.

"Mineral" shall include all minerals whatsoever other than coal.

"Joint-stock Company" shall mean any company incorporated for mining purposes under a Canadian charter or licensed by the Government of Canada.

"Mining Recorder" shall mean the official appointed by the gold commissioner to record applications and grant entries for claims in the mining divisions into which the commissioner may divide the Yukon District.

FREE MINERS AND THEIR PRIVILEGES.

1. Every person over but not under 18 years of age, and every joint-stock company, shall be entitled to all the rights and privileges of a free miner, under these regulations and under the regulations governing quartz mining, and shall be considered a free miner upon taking out a free-miner's certificate. A free miner's certificate issued to a joint-stock company shall be issued in its corporate name. A free-miner's certificate shall not be transferable.

2. A free-miner's certificate may be granted for one year to run from the date thereof or from the expiration of the applicant's then existing certificate, upon the payment therefor of the sum of $10, unless the certificate is to be issued in favor of a joint-stock company, in which case the fee shall be $50 for a company having a nominal captial of $100,000 or less, and for a company having a nominal capital exceeding $100,000, the fee shall be $100. Only one person or joint-stock company shall be named in a certificate.

3. Gives form of miner's certificate, and adds: This certificate shall also grant to the holder thereof the privileges of fishing and shooting, subject to the provisions of any act which has been passed, or which may hereafter be passed, for the protection of game and fish; also the privilege of cutting timber for actual necessities, for building houses, boats, and for general mining operations; such timber, however, to be for the exclusive use of the miner himself, but such permission shall not extend to timber which may have been heretofore or which may hereafter be granted to other persons or corporations.

4. Free-miner's certificates may be obtained by applicants in person at the Department of the Interior, Ottawa, or from the agents of Dominion Lands at Winnipeg, Manitoba; Calgary, Edmonton, Prince Albert, in the Northwest Territories; Kamloops and

New Westminster, in the Province of British Columbia; at Dawson City in the Yukon District; also from agents of the Government at Vancouver and Victoria, B. C., and at other places which may from time to time be named by the Minister of the Interior.

5. If any person or joint-stock company shall apply for a free-miner's certificate at the agent's office during his absence, and shall leave the fee required by these regulations, with the officer or other person in charge of said office, he or it shall be entitled to have such certificate from the date of such application; and any free miner shall at any time be entitled to obtain a free-miner's certificate commencing to run from the expiration of his then existing free-miner's certificate, provided that when he applies for such certificate he shall produce to the agent, or in case of his absence shall leave with the officer or other person in charge of the agent's office, such existing certificate.

6. If any free-miner's certificate be accidentally destroyed or lost, the owner thereof may, on payment of a fee of $2, have a true copy of it, signed by the agent, or other person by whom or out of whose office the original was issued. Every such copy shall be marked "Substituted Certificate"; and unless some material irregularity be shown in respect thereof, every original or substituted free-miner's certificate shall be evidence of all matters therein contained.

7. No person or joint-stock company will be recognized as having any right or interest in or to any placer claim, quartz claim, mining lease, bed-rock flume grant, or any minerals in any ground comprised therein, or in or to any water-right, mining ditch, drain, tunnel, or flume, unless he or it and every person in his or its employment shall have a free-miner's certificate unexpired. And on the expiration of a free-miner's certificate the owner thereof shall absolutely forfeit all his rights and interest in or to any placer claim, mining lease, bed-rock flume grant, and any minerals in any ground comprised therein, and in or to any and every water-right, mining ditch, drain, tunnel, or flume, which may be held or claimed by such owner of such expired free-miner's certificate, unless such owner shall, on or before the day following the expiration of such certificate, obtain a new free-miner's certificate. Provided, nevertheless, that should any co-owner fail to keep up his free-miner's certificate such failure shall not cause a forfeiture or act as an abandonment of the claim, but the interest of the co-owner who shall fail to keep up his free-miner's certificate shall, *ipso facto*, be and become vested in his co-owners, *pro rata* according to their former interests; provided, nevertheless, that a shareholder in a joint-stock company need not be a free miner, and, though not a free miner, shall be en-

titled to buy, sell, hold, or dispose of any shares therein.

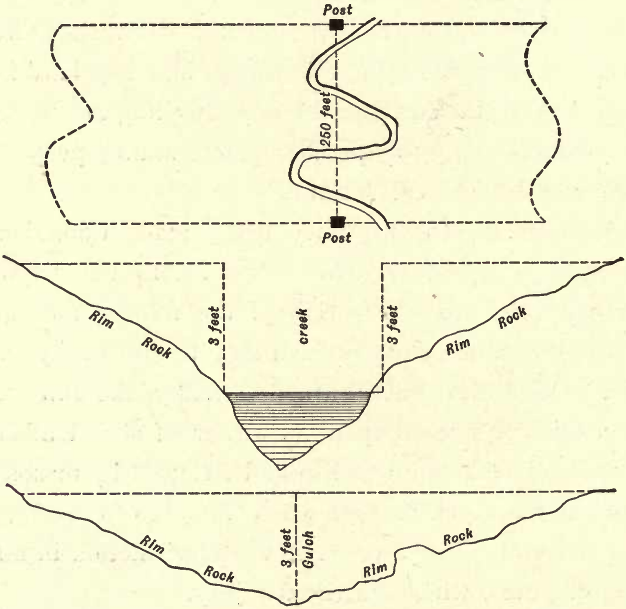
8. Every free miner shall, during the continuance of his certificate, but not longer, have the right to enter, locate, prospect, and mine for gold and other minerals upon any lands in the Yukon District, whether vested in the Crown or otherwise, except upon Government reservations for town sites, land which is occupied by any building, and any land falling within the curtilage of any dwelling-house, and any land lawfully occupied for placer-mining purposes, and also Indian reservations.

9. Previous to any entry being made upon lands lawfully occupied, such free miner shall give adequate security, to the satisfaction of the mining recorder, for any loss or damage which may be caused by such entry; and after such entry he shall make full compensation to the occupant or owner of such lands for any loss or damage which may be caused by reason of such entry; such compensation, in case of dispute, to be determined by a court having jurisdiction in mining disputes, with or without a jury.

NATURE AND SIZE OF CLAIMS.

10. A creek or gulch claim shall be 250 ft. long measured in the general direction of the creek or gulch. The boundaries of the claim which run in the

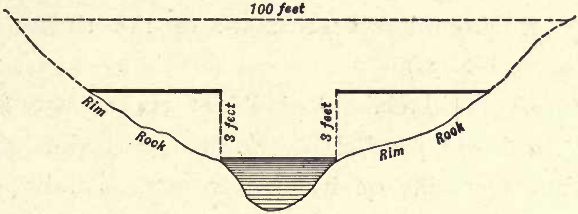
general direction of the creek or gulch shall be lines along bed or rim rock 3 ft. higher than the rim or edge of the creek, or the lowest general level of the gulch within the claim, so drawn or marked as to be at every point 3 ft. above the rim or edge of the creek or the lowest general level of the gulch, opposite



No. 1.—Plan and Sections of Creek and Gulch Claims.

to it at right angles to the general direction of the claim for its length, but such boundaries shall not in any case exceed 1000 ft. on each side of the centre of the stream or gulch. (See Diagram No. 1.)

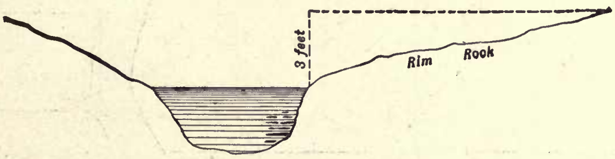
11. If the boundaries be less than 100 ft. apart horizontally, they shall be lines traced along bed or rim rock 100 ft. apart horizontally, following as nearly



No. 2.—Side Boundaries less than 100 Ft. Apart.

as practicable the direction of the valley for the length of the valley for the length of the claim. (See Diagram No. 2.)

12. A river claim shall be situated only on one side of the river and shall not exceed 250 ft. in length, measured in the general direction of the river. The other boundary of the claim which runs in the general direction of the river shall be lines along bed or rim



No. 3.—Section of River Claim.

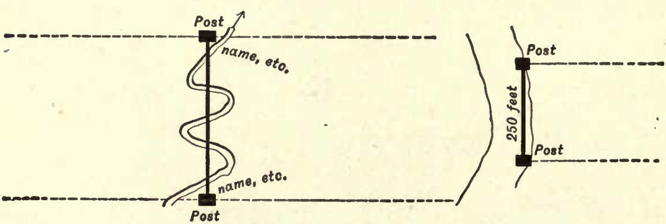
rock 3 ft. higher than the rim or edge of the river within the claim so drawn or marked as to be at every

point 3 ft. above the rim or edge of the river opposite to it at right angles to the general direction of the claim for its length, but such boundaries shall not in any case be less than 250 ft. or exceed a distance of 1000 ft. from low-water mark of the river. (See Diagram No. 3.)

13. A "hill claim" shall not exceed 250 ft. in length, drawn parallel to the main direction of the stream or ravine on which it fronts. Parallel lines drawn from each end of the base at right angles thereto, and running to the summit of the hill (provided the distance does not exceed 1000 ft.), shall constitute the end boundaries of the claim.

14. All other placer claims shall be 250 ft. square.

15. Every placer claim shall be as nearly as possible rectangular in form, and marked by two legal posts firmly fixed in the ground in the manner shown in Diagram No. 4. The line between the two posts



No. 4.—Staking Creek and River Claims.

shall be well cut out so that one post may, if the nature of the surface will permit, be seen from the

other. The flatted side of each post shall face the claim, and on each post shall be written on the side facing the claim, a legible notice stating the name or number of the claim, or both if possible, its length in feet, the date when staked, and the full Christian and surname of the locator.

16. Every alternate 10 claims shall be reserved for the Government of Canada. That is to say, when a claim is located the discoverer's claim and 9 additional claims adjoining each other and numbered consecutively will be open for registration. Then the next 10 claims of 250 ft. each will be reserved for the Government, and so on. The alternate group of claims reserved for the Crown shall be disposed of in such manner as may be decided by the Minister of the Interior.

17. The penalty for trespassing upon a claim reserved for the Crown shall be immediate cancellation by the mining recorder of any entry or entries which the person trespassing may have obtained, whether by original entry or purchase, for a mining claim, and the refusal by the mining recorder of the acceptance of any application which the person trespassing may at any time make for a claim. In addition to such penalty, the mounted police, upon a requisition from the mining recorder to that effect, shall take the necessary steps to eject the trespasser.

18. In defining the size of claims, they shall be measured horizontally irrespective of inequalities on the surface of the ground.

19. If any free miner or party of free miners discover a new mine, and such discovery shall be established to the satisfaction of the mining recorder, creek, river, or hill, claims of the following size shall be allowed, namely: To one discoverer, one claim, 500 ft. in length. To a party of two discoverers, two claims, amounting together to 1000 ft. in length. To each member of a party beyond two in number, a claim of the ordinary size only.

20. A new stratum of auriferous earth or gravel situated in a locality where the claims have been abandoned shall for this purpose be deemed a new mine, although the same locality shall have been previously worked at a different level.

21. The forms of application for a grant for placer mining, and the grant of the same, shall be those contained in forms H and I in the schedule hereto.

22. A claim shall be recorded with the mining recorder in whose district it is situated, within 10 days after the location thereof, if it is located within 10 miles of the mining-recorder's office. One extra day shall be allowed for every additional 10 miles or fraction thereof.

23. In the event of the claim being more than 100

miles from a recorder's office, and situated where other claims are being located, the free miners, not less than five in number, are authorized to meet and appoint one of their number a "Free-miners' Recorder," who shall act in that capacity until a mining recorder is appointed by the gold commissioner.

24. The free-miners' recorder shall, at the earliest possible date after his appointment, notify the nearest Government mining recorder thereof, and upon the arrival of the Government mining recorder he shall deliver to him his records and the fees received for recording the claims. The Government mining recorder shall then grant to each free miner whose name appears in the records an entry for his claim on form I of these regulations, provided an application has been made by him in accordance with form H thereof. The entry to date from the time the free-miners' recorder recorded the application.

25. If the free-miners' recorder fails within three months to notify the nearest Government mining recorder of his appointment, the claims which he may have recorded will be cancelled.

26. During the absence of the mining recorder from his office, the entry for a claim may be granted by any person whom he may appoint to perform his duties in his absence.

27. Entry shall not be granted for a claim which

has not been staked by the applicant in person in the manner specified in these regulations. An affidavit that the claim was staked out by the applicant shall be embodied in form H in the schedule hereto.

28. An entry fee of $15 shall be charged the first year, and an annual fee of $15 for each of the following years. This provision shall apply to claims for which entries have already been granted.

29. A statement of the entries granted and fees collected shall be rendered by the mining recorder to the gold commissioner at least every three months, which shall be accompanied by the amount collected.

30. A royalty of 10 per cent on the gold mined shall be levied and collected on the gross output of each claim. The royalty may be paid at banking offices to be established under the auspices of the Government of Canada, or to the gold commissioner, or to any mining recorder authorized by him. The sum of $2500 shall be deducted from the gross annual output of a claim when estimating the amount upon which royalty is to be calculated, but this exemption shall not be allowed unless the royalty is paid at a banking office or to the gold commissioner or mining recorder. When the royalty is paid monthly or at longer periods, the deduction shall be made ratable on the basis of $2500 per annum for the claim. If not paid to the bank, gold commissioner, or mining

recorder, it shall be collected by the custom officials or police officers when the miner passes the posts established at the boundary of a district. Such royalty to form part of the consolidated revenue, and to be accounted for by the officers who collect the same in due course. The time and manner in which such royalty shall be collected shall be provided for by regulations to be made by the gold commissioner.

31. Default in payment of such royalty, if continued for 10 days after notice has been posted on the claim in respect of which it is demanded, or in the vicinity of such claim, by the gold commissioner or his agent, shall be followed by cancellation of the claim. Any attempt to defraud the Crown by withholding any part of the revenue thus provided for, by making false statements of the amount taken out, shall be punished by cancellation of the claim in respect of which fraud or false statements have been committed or made. In respect to the facts as to such fraud or false statements or non-payment of royalty, the decision of the gold commissioner shall be final.

32. After the recording of a claim the removal of any post by the holder thereof or by any person acting in his behalf, for the purpose of changing the boundaries of his claim, shall act as a forfeiture of the claim.

33. The entry of every holder of a grant for placer

mining must be renewed and his receipt relinquished and replaced every year, the entry fee being paid each time.

34. The holder of a creek, gulch, or river claim may, within 60 days after staking out the claim, obtain an entry for a hill claim adjoining it, by paying to the mining recorder the sum of $100. This permission shall also be given to the holder of a creek, gulch, or river claim obtained under former regulations, provided that the hill claim is available at the time an application is made therefor.

35. No miner shall receive a grant of more than one mining claim in a mining district, the boundaries of which shall be defined by the mining recorder, but the same miner may also hold a hill claim, acquired by him under these regulations in connection with a creek, gulch, or river claim, and any number of claims by purchase; and any number of miners may unite to work their claims in common, upon such terms as they may arrange, provided such agreement is registered with the mining recorder and a fee of $5 paid for each registration.

36. Any free miner or miners may sell, mortgage, or dispose of his or their claims, provided such disposal be registered with, and a fee of $2 paid to, the mining recorder, who shall thereupon give the

assignee a certificate in the form J in the schedule hereto.

37. Every free miner shall during the continuance of his grant have the exclusive right of entry upon his own claim for the mine-like working thereof, and the construction of a residence thereon, and shall be entitled exclusively to all the proceeds realized therefrom, upon which, however, the royalty prescribed by these regulations shall be payable; provided that the mining recorder may grant to the holders of other claims such right of entry thereon as may be absolutely necessary for the working of their claims, upon such terms as may to him seem reasonable. He may also grant permits to miners to cut timber thereon for their own use.

38. Every free miner shall be entitled to the use of so much of the water naturally flowing through or past his claim, and not already lawfully appropriated, as shall, in the opinion of the mining recorder, be necessary for the due working thereof, and shall be entitled to drain his own claim free of charge.

39. A claim shall be deemed to be abandoned and open to occupation and entry by any person when the same shall have remained unworked on working days, excepting during the close season, by the grantee thereof or by some person on his behalf for the space of 72 hours, unless sickness or other reasonable cause

be shown to the satisfaction of the mining recorder, or unless the grantee is absent on leave given by the mining recorder, and the mining recorder, upon obtaining evidence satisfactory to himself that this provision is not being complied with, may cancel the entry given for a claim.

40. If any cases arise for which no provision is made in these regulations, the provisions of the regulations governing the disposal of mineral lands other than coal lands, approved by His Excellency the Governor in Council on November 9, 1889, or such other regulations as may be substituted therefor, shall apply. (Appended to Section 40 are the forms for applications, certificates, etc., referred to in the text.)

REGULATIONS GOVERNING RIVER-BED DREDGING FOR GOLD.

The following are the regulations for the issues of leases to persons or companies who have obtained a free-miner's certificate in accordance with the provisions of the regulations governing placer mining in the Provisional District of Yukon, to dredge for minerals other than coal in the submerged beds or bars of rivers in the Provisional District of Yukon, in the Northwest Territories:

1. The lessee shall be given the exclusive right to

subaqueous mining and dredging for all minerals with the exception of coal in and along an unbroken extent of five miles of a river following its sinuosities, to be measured down the middle thereof, and to be described by the lessee in such manner as to be easily traced on the ground; and although the lessee may also obtain as many as five other leases, each for an unbroken extent of five miles of a river, so measured and described, no more than six such leases will be issued in favor of an individual or company, so that the maximum extent of river in and along which any individual or company shall be given the exclusive right above mentioned, shall under no circumstances exceed 30 miles. The lease shall provide for the survey of the leasehold under instructions from the Surveyor General, and for the filing of the returns of survey in the Department of the Interior within one year from the date of the lease.

2. The lease shall be for a term of 20 years, at the end of which time all rights vested in, or which may be claimed by the lessee under his lease, are to cease and determine. The lease may be renewable, however, from time to time thereafter in the discretion of the Minister of the Interior.

3. The lessee's right of mining and dredging shall be confined to the submerged beds or bars in the river below low-water mark, that boundary to be fixed by

its position on the first day of August in the year of the date of the lease.

4. The lease shall be subject to the rights of all persons who have received or who may receive entries for claims under the Placer-mining Regulations.

5. The lessee shall have at least one dredge in operation upon the five miles of river leased to him, within two seasons from the date of his lease, and if, during one season when operations can be carried on, he fails to efficiently work the same to the satisfaction of the Minister of the Interior, the lease shall become null and void unless the Minister of the Interior shall otherwise decide. Provided that when any company or individual has obtained more than one lease, one dredge for each 15 miles or portion thereof shall be held to be compliance with this regulation.

6. The lessee shall pay a rental of $100 per annum for each mile of river so leased to him. The lessee shall also pay to the Crown a royalty of 10 per cent on the output in excess of $15,000, as shown by sworn returns to be furnished monthly by the lessee to the gold commissioner during the period that dredging operations are being carried on; such royalty, if any, to be paid with each return.

7. The lessee who is the holder of more than one lease shall be entitled to the exemption as to royalty provided for by the next preceding regulation to the

extent of $15,000 for each five miles of river for which he is the holder of a lease; but the lessee under one lease shall not be entitled to the exemption as to royalty provided by the next two preceding regulations, where the dredge or dredges used by him have been used in dredging by another lessee, or in any case in respect of more than 30 miles.

8. The lessee shall be permitted to cut free of all dues, on any land belonging to the Crown, such timber as may be necessary for the purposes of his lease, but such permission shall not extend to timber which may have been heretofore or may hereafter be granted to other persons or corporations.

9. The lessee shall not interfere in any way with the general right of the public to use the river in which he may be permitted to dredge, for navigation and other purposes; the free navigation of the river shall not be impeded by the deposit of tailings in such manner as to form bars or banks in the channel thereof, and the current or stream shall not be obstructed in any material degree by the accumulation of such deposits.

10. The lease shall provide that any person who has received or who may receive entry under the Placer-mining Regulations shall be entitled to run tailings into the river at any point thereon, and to construct all works which may be necessary for prop-

erly operating and working his claim. Provided that it shall not be lawful for such person to construct a wing-dam within 1000 ft. from the place where any dredge is being operated, nor to obstruct or interfere in any way with the operation of any dredge.

11. The lease shall reserve all roads, ways, bridges, drains, and other public works, and all improvement now existing, or which may hereafter be made in, upon, or under any part of the river, and the power to enter and construct the same, and shall provide that the lessee shall not damage nor obstruct any public ways, drains, bridges, works, and improvements now or hereafter to be made upon, in, over, through, or under the river; and that he will substantially bridge or cover and protect all the cuts, flumes, ditches, and sluices, and all pits and dangerous places at all points where they may be crossed by a public highway or frequented path or trail, to the satisfaction of the Minister of the Interior.

12. That the lessee, his executors, administrators, or assigns, shall not nor will assign, transfer, or sublet the demised premises, or any part thereof, without the consent in writing of the Minister first had and obtained.

LAW RELATIVE TO RIVER DREDGING.

Rivers or streams in a defined channel belong to the State. To dredge river beds requires either a grant or prescription from the State, in the absence of any definite legislation regulating this industry. There is scarcely any doubt that the State would grant permission to mine any river bed within her borders provided navigation were not hindered or obstructed or riparian rights interfered with, but such sanction should be obtained prior to commencing work. In the case of a non navigable stream flowing within the borders of one's land, the land under the water belongs to the landowner; or the water, to the State. In such a case the right to dredge is unquestionable. Or in case of two landowners adjoining on opposite sides either one may dredge his half and be convicted of trespass if he oversteps the boundary. The owner or owners must not overstep the mark and injure land or watercourse below their property, otherwise they may be enjoined.

The dredging company may purchase a piece of land and work their dredge along the river-bank. They must not, however, change the course of the stream or divert it from the riparian owner opposite, although they may work as far inland on their own property as they desire, and have the usufruct of the

stream. The chances are that dredgers if they pollute the streams or make them muddy will have trouble with riparian owners in the States for creating a nuisance. The washing of ore and discoloring the water of the New River, Virginia, has caused much comment, and an attempt has been made in Congress to suppress it.

If the stream belongs to the public domain, twenty acres can be located, or a dredger may work up and down the stream (provided it does not work on a located claim) without interference.

INFORMATION ON HYDRAULICS.

THE following tables have been computed by data obtained from careful experiments made by the ablest engineers.

GOLD TABLE

FOR DETERMINING THE VALUE OF FREE GOLD PER TON (2000 LBS.) OF QUARTZ OR CUBIC YARD OF GRAVEL,

PREPARED BY

MELVILLE ATWOOD, Esq., F.G.S., *Consulting Mining Engineer.*

Weight Washed Gold. 4-lb. Sample. Grains.	Fineness, 780. Value per Oz. $16.12.	Fineness, 830. Value per Oz. $17.15.	Fineness, 875. Value per Oz. $18.08.	Fineness, 920. Value per Oz. $19 01.
5 grains	$83.97	$89.36	$94.20	$99.05
4 "	67.18	71.49	75 36	79.24
3 "	50.38	53.61	56.52	59.43
2 "	33.59	35.74	37.68	39.62
1 "	16.79	17 87	18.84	19.81
.9 "	15.11	16.08	16.95	17.82
.8 "	13.43	14.29	15.07	15.84
.7 "	11.75	12.51	13.19	13.86
.6 "	10.07	10.73	11.30	11.88
.5 "	8 40	8.93	9 42	9.90
.4 "	6.71	7.14	7.53	7.92
.3 "	5.03	5.36	5.65	5.94
.2 "	3.36	3.57	3.76	3 96
.1 "	1.68	1.78	1.88	1.98

They will therefore assist the unskilled as well as the skilled in many problems. However, to thoroughly understand the subject, one should purchase a text-book on Hydraulics.

These tables are reliable, and will prove correct as far as they go.

The whole subject has been touched upon in the preceding pages, so that any one who has carefully read them should understand the tables at a glance, and be able to apply them in practice.

EXPLANATION OF TABLE.

The foregoing table furnishes an exceedingly simple method of determining the value of *free gold* in a ton of gold-bearing quartz, or a cubic yard of auriferous gravel.

Take a sample of four (4) pounds of quartz, pulverize it to the usual fineness for horning, wash it carefully by batea or other means, amalgamate the gold by the application of quicksilver, volatilize the quicksilver by blowpipe or otherwise, weigh the resulting button, and the value given in the table opposite such weight will be the value in free gold per ton of 2000 pounds of quartz.

Example.—Sample of four pounds produces button weighing one grain, the finest of the gold being 830;

then the value of one ton of such quartz will be $17.87.

If the sample of four pounds should produce a button weighing say two and four-tenths ($2\frac{4}{10}$) grains, then the value of such quartz would be (875 fine) as follows, viz.:

Opposite 2 grains,	875 fine,	value	$37.68
" $\frac{4}{10}$ "	875 "	"	7.53
Total value per ton (2000 lbs.)...			$45.21

GOLD VALUE OF A CUBIC YARD OF GRAVEL.

To determine the gold value of a cubic yard of auriferous gravel the foregoing table can be used.

Take a sample of sixty (60) pounds of gravel, pulverize it, and carefully wash it by batea, pan, or otherwise; amalgamate the gold, volatilize the quicksilver, weigh the button, and in column in foregoing table, opposite the weight, will be found the gold value of a cubic yard of the gravel.

Example.—Sample of sixty pounds produces button weighing one grain, the fineness of the gold being 780; then the value of one cubic yard of such gravel would be $1.67. This is arrived at by pointing off one point, or dividing the value given in table by 10.

If the sample of sixty pounds yields a button weigh-

ing one grain and two-tenths ($1\frac{2}{10}$ grains), then the value of the gravel per cubic yard would be—gold being 920 fine—as follows:

Opposite 1 grain,	920 fine,	value	$1.98
" $\frac{2}{10}$ "	920 "	"	.03 +
Total value cubic yard			$2.01 +

This table is prepared upon the following basis of weights, viz.: A sample of four pounds of quartz is the one-five-hundredth part in weight of a ton of 2000 pounds, and the gold values given are reduced to this proportion.

Eighteen cubic feet of gravel in bank will weigh one ton, or 2000 pounds, and a cubic yard, or twenty-seven cubic feet, will weigh 3000 pounds, or $1\frac{1}{2}$ tons; and sixty pounds being the one-fiftieth part of the weight of a cubic yard, then the relative proportion of the weight of quartz to gravel is as 50 to 500, or 1 to 10.

HYDRAULICS.

1 gallon of water = 231 cubic inches and weighs 8.3389 pounds; figured at $8\frac{1}{3}$ pounds.

1 cubic foot of water = 1728 cubic inches and weighs 62.3793 pounds; figured at 62.5.
contains 7.48052 gallons, usually figured at 7.5.

A column of water 2.31 feet high gives 1 lb. pressure on each square inch of its base.

A column of water 1 ft. high will give a pressure of .434 lbs. on each square inch of base. Usually reckoned at 5 lb. per ft. in height.

Doubling the diameter of a pipe increases its area four times, hence its capacity.

Doubling the diameter of a pipe increases its frictional rubbing-surface two times.

To double the quantity of water flowing through a pipe under a given head requires eight times the power.

27,154 inches of water will spread 1 inch deep over 1 acre of ground, and weigh 101 tons.

A foot-pound of work is the expenditure of power required to raise one pound one foot high in one minute.

A horse-power is 33,000 foot-pounds, or what a strong horse can do 10 hours daily every minute in the day. Average horses can do but 22,000 ft.-lbs. per minute.

To find the horse-power required to raise water? Multiply the number of pounds of water to be raised per minute by the height from the level of the water to the level of discharge.

FOR USUAL CALCULATIONS.

A flow of one miners' inch of water is equal to the supply of—

	Gallons.	Cubic Feet.
Per second	.1875	.025
Per minute	11.25	1.5
Per hour	675.	90.00
Per day	16200	2160.

Or, a flow of one cubic foot,

Per second equals 40 miners' inches;

Per minute equals $\frac{2}{3}$ miners' inch;

Per hour equals .01110 + miners' inch.

TABLES FOR CALCULATING THE HORSE-POWER OF WATER.

MINERS'-INCH TABLE.

The following table gives the horse-power of one miners' inch of water under heads from one up to eleven hundred feet. This inch equals 1½ cubic feet per minute.

Head in Feet.	Horse-power.	Head in Feet.	Horse-power.
1	.0024147	320	.772704
20	.0482294	330	.796851
30	.072441	340	.820998
40	.096588	350	.845145
50	.120735	360	.869292
60	.144882	370	.893439
70	.169029	380	.917586
80	.193176	390	.941733
90	.217323	400	.965880
100	.241470	410	.990027
110	.265617	420	1.014174
120	.289764	430	1.038321
130	.313911	440	1.062468
140	.338058	450	1.086615
150	.362205	460	1.110762
160	.386352	470	1.134909
170	.410499	480	1.159056
180	.434646	490	1.183206
190	.458793	500	1.207350
200	.482940	520	1.255644
210	.507087	540	1.303938
220	.531234	560	1.352232
230	.555381	580	1.400526
240	.579528	600	1.448820
250	.603675	650	1.569555
260	.627822	700	1.690290
270	.651969	750	1.811025
280	.676116	800	1.931760
290	.700263	900	2.173230
300	.724410	1000	2.414700
310	.748557	1100	2.656170

WHEN THE EXACT HEAD IS FOUND IN ABOVE TABLE.

Example.—Have 100-foot head and 50 inches of water. How many horse-power?

By reference to above table the horse-power of 1 inch under 100 feet head is .241470. This amount multiplied by the number of inches, 50, will give 12.07 horse-power.

CUBIC-FEET TABLE.

The following table gives the horse-power of one cubic foot of water per minute under heads from one up to eleven hundred feet:

Head in Feet.	Horse-power.	Head in Feet.	Horse-power.
1	.0016098	320	.515136
20	.032196	330	.531234
30	.048294	340	.547332
40	.064392	350	.563430
50	.080490	360	.579528
60	.096588	370	.595626
70	.112686	380	.611724
80	.128784	390	.627822
90	.144892	400	.643920
100	.160980	410	.660018
110	.177078	420	.676116
120	.193176	430	.692214
130	.209274	440	.708312
140	.225372	450	.724410
150	.241470	460	.740508
160	.257568	470	.756606
170	.273666	480	.772704
180	.289764	490	.788802
190	.305862	500	.804900
200	.321960	520	.837096
210	.338058	540	.869292
220	.354156	560	.901488
230	.370254	580	.933684
240	.386352	600	.965880
250	.402450	650	1.046370
260	.418548	700	1.126860
270	.434646	750	1.207350
280	.450744	800	1.287840
290	.466842	900	1.448820
300	.482940	1000	1.609800
310	.499038	1100	1.770780

WHEN EXACT HEAD IS NOT FOUND IN TABLE.

Take the horse-power of 1 inch under 1-foot head and multiply by the number of inches, and then by number of feet head. The product will be the required horse-power.

Note.—The above formula will answer for the cubic-feet table, by substituting the equivalents therein for those of miners' inches.

Horse-power given in above table equal 85 *per cent of theoretical power.*

FLOW OF WATER THROUGH CLEAN IRON PIPES.

REMARKS.—In the analysis of the flow of water, the total head is divided into three parts, viz.: 1st, that portion of the head due to the velocity; 2d, that portion which overcomes the resistance of entry; and 3d, that portion which overcomes the resistance within the pipe. In long pipes, the two former portions as compared with the latter portion of the total head are quite small. In this table the greatest velocity in any pipe is 13.445 feet per second, due to 4.2 feet, the sum of the first and second portions of the total head, while the third portion of the head is 211.2 feet. The head or fall in this table refers to the third portion of the total head. This table has been computed on the assumption that the length of any pipe is not less than 1000 times its diameter.

Question: The fall being 52.8 feet per mile, what will be the flow through a pipe 22 inches diameter, in cubic feet, also in miners' inches?

Answer: In this table find in first column 52.8 feet, opposite which in column headed 22 inches will be found the required quantity, viz., 21.06 cubic feet, which multiplied by 50 gives 1053 miners' inches.

Question: The diameter of the pipe being 24 inches, what fall will be required for the pipe to carry 1000 miners' inches?

Answer: In this table, in column headed 24 inches, find that number which multiplied by 50 will make the 1000 miners' inches given. In this case the nearest number is 20.42, opposite which in column headed fall per mile will be found 31.68 feet, the fall required.

Question: In carrying 1050 inches of water to a hydraulic mine in a pipe 27 inches diameter, having a fall of 95.04 feet to the mile, what will be the effective head at the mine?

Answer: In this table, in column headed 27 inches, find that number which multiplied by 50 will make 1050 approximate miners' inches. In this case we have 21.13 cubic feet, opposite which in column headed fall per mile we find 18.48 feet, which is the head per mile lost in carrying the water. Subtracting this from the given fall or head gives the effective head. Thus $95.04 - 18.48 = 76.56$ feet effective head.

Question: There being 7.5 gallons in a cubic foot, and 86,400 seconds in a day (twenty-four hours), the fall 7.39 feet per mile, how many gallons will a pipe 40 inches diameter carry per day?

Answer: In this table, in column headed 40 inches and opposite 7.39 feet headed fall per mile, will be found 37.57 cubic feet flow per second. Then $37.57 \times 7.5 \times 86{,}400 = 24{,}345{,}360$ gallons.

General Rule.—The velocity per second is equal to 50 times the square root of the product of the head and diameter in feet, divided by the sum of the length and 50 times the diameter of the pipe in feet.

Short Pipes.—This rule applies to both long and short pipes, and is approximately accurate if the diameter does not exceed two feet.

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES.

Fall Per Mile.	Fall Per Rod.		Diameters.					
			½ in.	¾ in.	1 in.	1½ in.	1¾ in.	2 in.
Feet.	Ft.	In.	Cu Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.
21.12	0	0.792	....	....	....	....	....	.02584
26.40	0	9.990	....	....	....	....	.02014	.02924
31.68	0	1.188	....	....	....	.01460	.02270	.03274
36.96	0	1.396	....	....	....	.01583	.02426	.03492
42.24	0	1.584	....	....	.00567	.01707	.02638	.03776
47.52	0	1.782	....	....	.00617	.01816	.02838	.04081
52.80	0	1.980	....	.00316	.00677	.01963	.02988	.04321
63.36	0	2.376	.00122	.00350	.00781	.02123	.03260	.04843
73.92	0	2.772	.00124	.00377	.00841	.02282	.03556	.05150
84.48	0	3.168	.00135	.00411	.00886	.02466	.03706	.05456
95.04	0	3.564	.00143	.00445	.00961	.02577	.03923	.05740
105.60	0	3.960	.00150	.00466	.00990	.02793	.04224	.06111
158.40	0	5.940	.00197	.00589	.01245	.03458	.05175	.07399
211.20	0	7.920	.00241	.00705	.01492	.04132	.06167	.08734
264.00	0	9.900	.00279	.00798	.01666	.04577	.07145	.1095
316.80	0	11.880	.00315	.00874	.01857	.05043	.07830	.1200
369.60	1	1.86	.00340	.00951	.01988	.05424	.08381	.1288
422.40	1	3.84	.00366	.01012	.02141	.05804	.08949	.1375
475.20	1	5.82	.00389	.01086	.02283	.06191	.09400	.1442
528 00	1	7.80	.00410	.01144	.02424	.06724	.10030	.1523
633.00	1	11.76	.00453	.01282	.02676	.07400	.1110	.1634
739.20	2	3.72	.00473	.01380	.02890	.08020	.1200	.1748
844.00	2	7.68	.00524	.01480	.03081	.08622	.1285	.1855
950.40	2	11.64	.00559	.01567	.03276	.09225	.1372	.1955
1056.00	3	3.60	.00589	.01656	.03458	.09692	.1450	.2047
1320.00	4	1.50	.00660	.01871	.03897	.1079	.1617	.2276
1584.00	4	11.40	.00732	.02064	.04316	.1187	.1773	.2483
2112.00	6	7.20	.00855	.02390	.04987	.1380	.2050	.2833
2640.00	8	3.00	.00966	.02705	.05648	.1550	....	......
3168.00	9	10.80	.01065	.03003	.06320	....	....	......
3696.00	11	6.60	.01156	.03301	.06943	....	....	......
4224.00	13	2.40	.01248	.03572	....	....	....	......
4752.00	14	10.20	.01338	.03786	....	....	....	......
5280.00	16	5.00	.01419	....	....	....	....	......

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES.

Fall Per Mile. Feet.	Fall Per Rod. Ft.	In.	Diameters. 3 in. Cu. Ft.	4 in. Cu. Ft.	6 in. Cu. Ft.	8 in. Cu. Ft.	10 in. Cu. Ft.	11 in. Cu. Ft.	12 in Cu. Ft.
5.280	0	0.198	......	......	......	......	......	......	1.265
6.336	0	0.238	......	......	......	......	.878	1.120	1.402
7.392	0	0.277	......	......	......	.....	.960	1.221	1.489
8.448	0	0.317	......	......	......	.573	1.047	1.320	1.634
9.504	0	0.356	......	......	......	.611	1.110	1.394	1.728
10.560	0	0.396	......	......	.298	.639	1.194	1.490	1.826
11.616	0	0.436	......	......	.314	.659	1.265	1.580	1.940
12.672	0	0.475	......	......	.330	.703	1.325	1.653	2.026
13.728	0	0.515	......	.1235	.346	.737	1.377	1.722	2.117
14.784	0	0.554	......	.1298	.359	.768	1.423	1.788	2.207
15.840	0	0.594	.0630	.1335	.377	.808	1.470	1.854	2.297
18.480	0	0.684	.0692	.1465	.395	.876	1.587	1.996	2.466
21.120	0	0.792	.0749	.1562	.444	.931	1.683	2.136	2.662
26.400	0	0.990	.0839	.1771	.496	1.045	1.865	2.397	3.020
31.680	0	1.188	.0915	.1923	.548	1.575	2.059	2.636	3.310
36.960	0	1.386	.0992	.2146	.589	1.262	2.222	2.858	3.601
42.240	0	1.584	.1060	.2339	.631	1.344	2.383	3.062	3.856
47.520	0	1.782	.1119	.2460	.672	1.424	2.514	3.232	4.072
52.800	0	1.980	.1190	.2582	.721	1.496	2.662	3.419	4.305
63.360	0	2.376	.1313	.2893	.784	1.644	2.932	3.760	4.728
73.920	0	2.772	.1413	.3036	.858	1.782	3.210	4.016	5.094
84.480	0	3.168	.1507	.3237	.922	1.916	3.450	4.390	5.482
95.040	0	3.564	.1590	.3412	.975	2.033	3 679	4.679	5 839
105.600	0	3.960	.1717	.3607	1.022	2.155	3.856	5.251	6.160
158.400	0	5.940	.2081	.4503	1.263	2.667	4.762	6.086	7.630
211.200	0	7.920	.2469	.5331	1.484	3.145	5.563	7 022	8.860
264.000	0	9.900	.2785	.5954	1.665	3 513	6.704	8.244	9.967
316.800	0	11.880	.3049	.6390	1.929	3.847	......	......	......
369.000	1	1.860	.3331	.6967	1.976	4.196	......	......	......
422.400	1	3.840	.3559	.7506	2.144	......	......	......	......
475.200	1	5.820	.3816	.7960	2.274	......	......	......	......
528.000	1	7.800	.4043	.9464	2.399	......	......	......	......
633.600	1	11.760	.4440	.9270	......	......	......	......	......
739.200	2	3.720	.4977	1.0060	......	......	......	......	......
844.800	2	7.680	.5131	1.0810	......	......	......	......	......
950.400	2	11.640	.5436	......	......	......	......	......	......
1056.000	3	3.600	.5832	......	......	......	......	......	......
1320.000	4	1.500	.6523	......	......	......	......	......	......
1584.000	4	11.400	......	......	......	......	......	......	......

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES—(*continued.*)

Fall per Mile.	Fall per Rod.		Diameters.							
			14 In.	15 In.	16 In.	18 In.	20 In.	22 In.	24 In.	27 In.
Feet.	Ft.	In.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. ft.	Cu.Ft.
2.11	0	0.08	......	....	......	......	....	......	......	....
2.64	0	0.10	......	....	......	....	....	......	......	8.27
3.17	0	0.12	......	......	....	......	3.61	4.61	6.10	8.37
3.70	0	0.14	......	......	2.25	3.10	4.07	5.25	6.64	9.09
4.22	0	0.16	1.71	2.05	2.43	3.27	4.35	5.62	7.13	9.48
4.75	0	0.18	1.83	2.19	2.59	3.49	4.68	6.01	7.56	10.26
5.28	0	0.20	1.91	2.30	2.72	3.66	4.92	6.32	7.95	10.74
5.81	0	0.22	2.02	2.43	2.88	3.88	5.15	6.62	8.34	11.45
6.34	0	0.24	2.11	2.54	3.02	4.06	5.40	6.94	8.75	11.93
6.86	0	0.26	2.18	2.65	3.18	4.23	5.62	7.24	9.14	12.54
7.39	0	0.28	2.27	2.75	3.28	4.40	5.82	7.51	9.47	12.96
7.92	0	0.30	2.35	2.84	3.39	4.61	6.05	7.78	9.80	13.49
8.45	0	0.32	2.44	2.94	3.49	4.75	6.27	8.03	10.13	13.98
8.98	0	0.34	2.54	2.98	3.62	4.90	6.48	8.36	10.57	14.41
9.50	0	0.36	2.59	3.11	3.69	5.03	6.65	8.55	10.77	14.81
10.03	0	0.38	2.67	3.21	3.81	5.17	6.92	8.85	11.10	15.21
10.56	0	0.40	2.72	3.29	3.92	5.30	7.05	9.07	11.43	15.63
11.62	0	0.44	2.88	3.47	4.12	5.63	7.42	9.55	12.05	16.44
12.67	0	0.48	3.02	3.63	4.32	5.87	7.79	10.01	12.01	17.23
13.73	0	0.51	3.15	3.79	4.51	6.18	8.14	10.48	13.23	18.01
14.78	0	0.55	3.29	3.95	4.68	6.38	8.48	10.91	13.79	18.75
15.84	0	0.59	3.42	4.11	4.87	6.64	8.77	11.29	14.25	19.50
18.48	0	0.69	3.62	4.46	5.31	7.17	9.49	12.25	15.50	21.13
21.12	0	0.79	3.99	4.78	5.67	7.65	10.16	13.12	16.62	22.62
26.40	0	0.99	4.46	5.37	6.39	8.66	11.43	14.78	18.71	25.34
31.68	0	1.19	4.91	5.91	7.02	9.54	12.59	16.20	20.42	27.74
36.96	0	1.39	5.37	6.45	7.66	10.33	13.66	17.53	22.05	29.96
42.24	0	1.59	5.77	6.90	8.16	11.09	14.66	18.78	23.61	31.99
47.52	0	1.78	6.11	7.31	8.64	11.71	15.54	19.93	25.07	33.97
52.80	0	1.98	6.44	7.70	9.10	12.37	16.47	21.06	26.42	35.89
63.36	0	2.38	7.00	8.39	9.95	13.65	17.99	23.07	29.03	39.76
73.92	0	2.77	7.60	9.15	10.87	14.75	19.49	24.68	31.49	43.22
84.48	0	3.17	8.17	9.81	11.63	15.84	21.03	26.97	33.90	46.57
95.04	0	3.56	8.93	10.47	12.43	16.90	22.45	29.70	36.18	48.06
105.60	0	3.96	9.26	11.09	13.14	17.85	23.56	31.15	38.45	.....
158.40	0	5.94	11.39	13.66	16.17	21.86	28.86	.. ..	......	.....
211.20	0	7.92	13.22	15.84	18.77	....	....	......	......	.....

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES—(*continued.*)

Fall per Mile. Feet.	Fall per Rod. Ft.	In.	Diameters. 30 In. Cu. Ft.	33 In. Cu. Ft.	36 In. Cu. Ft.	40 In. Cu. Ft.	44 In. Cu. Ft.	48 In. Cu. Ft.
1.06	0	0.04	....	... .	10.29	13.88	18.15	22.98
1.58	0	0.06	7.78	10.21	12.70	17.00	22.22	27.89
2.11	0	0.08	8.99	11.65	14.56	19.68	25.55	32.93
2.64	0	0.10	10.24	12.92	16.35	22.08	28.87	37.00
3.17	0	0.12	10.97	13.99	18.02	24.43	31.46	40.21
3.70	0	0.14	11.90	15.14	19.76	26.27	34.47	43.67
4.22	0	0.16	12.84	16.36	20.85	28.14	37.05	46.81
4.75	0	0.18	13.48	17.58	22.30	29.80	39.01	49.06
5.28	0	0.20	14.21	18.74	23.47	31.46	41.06	52.15
5.81	0	0.22	15.05	19.54	24.91	33.25	42.09	54.95
6 34	0	0.24	15.81	20.28	26.12	34.68	44.97	57.36
6.86	0	0.26	16.47	21.29	27.20	36.21	46.77	60.07
7.39	0	0.28	17.18	22.20	28.24	37.57	48.83	62.02
7.92	0	0.30	17.94	23.01	29.19	39.18	50.62	64.47
8.45	0	0.32	18.58	23.76	30.29	40.54	52.46	66.53
8.98	0	0.34	19.21	24.47	31.42	41.88	54.04	68.50
9.50	0	0.36	19.66	25.22	32.48	43 07	55.48	70.62
10.03	0	0.38	20.32	26.14	33.40	44.28	57.01	72.75
10.56	0	0.40	20.79	26.94	34.49	45.20	58.85	74.44
11.62	0	0.44	21.80	28.27	36.15	48.12	61.71	78.29
12.67	0	0.48	22.83	29.02	37.74	50.48	64.35	81.68
13.73	0	0.51	23.93	31.06	39.40	52.67	66.87	85.20
14.78	0	0.55	24.86	32.28	40.86	55.04	69.57	88.46
15.84	0	0.59	25.87	33.62	42.28	56.33	72.32	91.73
18.48	0	0.69	27.96	36.17	45.95	61.09	77.95	100.40
21.12	0	0.79	29.84	38.57	48 83	65.41	83.60	105.89
26.40	0	0.99	33.55	43.12	54.89	73.09	93.37	119.34
31.68	0	1.19	36.79	47.40	59.95	80.32	103.28	130.88
36.96	0	1.39	39.66	51.35	65.17	86.70	111.74	148.09
42.24	0	1.59	42.39	54.91	69.80	92 58	119.93	153.94
47.52	0	1.78	45.23	58.20	74.33	98.00	128.26	....
52.80	0	1.98	47.71	61.62	78.46	103.99	......	....
63.36	0	2.38	52.91	68.00	82.84	... ...	......	....
73.92	0	2.77	57.65	73.95	....	....	......	....

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES—(*continued.*)

Fall Per Mile.	Fall Per Rod.		Diameters.				
			54 In.	60 In.	72 In.	84 In.	96 In.
Feet.	Ft.	In.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.	Cu. Ft.
.53	0	0.02	21.96	29.77	46.99	75.43	107.77
1.06	0	0.04	31.70	38.19	57.65	104.61	152.45
1.58	0	0.06	38.53	52.09	82.53	126.18	188.45
2.11	0	0.08	45.12	59 04	95.99	145.43	218.75
2.64	0	0.10	50.23	67.56	109 42	162.75	245.30
3.17	0	0.12	55.51	74.32	121.58	177.03	267.41
3.70	0	0.14	60.21	80.51	132.04	192.04	290.53
4 22	0	0.16	63.61	86.30	139.96	207.81	310.89
4.75	0	0.18	67.20	91.99	148.72	222.44	324.20
5.28	0	0.20	72.37	96 98	157.77	235.13	350.45
5.81	0	0.22	75.71	102.39	165.97	253.34	366 19
6.34	0	0.24	79.13	107.31	173 04	264.77	382.02
6.86	0	0.26	82.54	115.53	179.26	275.16	397.85
7.39	0	0.28	85.90	116.53	187.46	287.67	414.70
7.92	0	0.30	89.52	119.68	193.93	296.37	427.76
8.45	0	0.32	92.43	123.70	200.18	307.87	443.09
8.98	0	0.34	95.35	127.63	206.40	316.15	457.42
9.50	0	0.36	97.65	131.26	212.05	326.73	470.49
10.03	c	0.38	100.19	134.79	217.71	335.79	481.53
10.56	0	0.40	103.82	138.84	225.21	348.25	496.37
11.62	0	0.44	108 78	145 98	235.52	364.92	522.76
12.67	0	0.48	113.47	152.56	246.41	389.09	547.88
13.73	0	0.51	118.48	158 65	256.17	394.43	510.01
14.78	0	0.55	123.10	164.54	267.19	408.36	592.13
15.84	0	0.59	128.19	170.43	277.88	423.36	612.00
18.48	0	0.69	138.92	183.98	299.72	482.99	....
21.12	0	0.79	147.91	197.52	320.74	....	....
26.40	0	0.99	165 80	221.95	358.52	....	....
31.68	0	1 19	182.42	244.26	.. ....	....	....
36.96	0	1.39	190.01	.. ....	....	....	....

RELATION OF CLEAN, SLIGHTLY ROUGH, AND VERY ROUGH PIPES WITH RESPECT TO THEIR CARRYING CAPACITY.

CLEAN PIPES.—The tables, as appear by the headings, have been computed for clean pipes, in other words, smooth and straight.

SLIGHTLY ROUGH PIPES.—When the pipe is slightly rough, multiply the tabulated number for clean pipes by the decimal .886 to determine its carrying capacity.

VERY ROUGH PIPES.—If the pipe is *very rough*, multiply the tabulated number for clean pipes by the decimal .773 to determine its carrying capacity.

RELATION OF THE INLET FORMS OF PIPES WITH RESPECT TO THE COEFFICIENTS OF ENTRANCE.

COEFFICIENTS.—Of the three following forms, viz., *Bell-mouthed*, *Square-edged*, and *Square-edged* projecting into the reservoir, their coefficients will be in order .900, .836, and .734.

ANGULAR BENDS AND TABLE.

ADDITIONAL HEAD REQUIRED TO OVERCOME ONE ANGULAR BEND.

Question: The velocity being 40 feet per second, what additional head is required to overcome the resistance of an angular bend whose angle of deflection is 90 degrees?

Answer: In this table find, in column headed "Velocity per Second," 40, opposite which, in column headed "90 degrees *Head*," will be found 24.45 feet, the additional head required.

TABLE SHOWING ADDITIONAL HEAD REQUIRED TO OVERCOME THE RESISTANCE OF ONE ANGULAR BEND.

Velocity per Second.	Angles of Deflection.					
Feet.	15° Head. Feet.	30° Head. Feet.	40° Head. Feet.	60° Head. Feet.	90° Head. Feet.	120° Head. Feet.
1	.0002	.0005	.002	.006	.015	.029
2	.0010	.0019	.009	.023	.061	.116
3	.0022	.0042	.019	.051	.138	.260
4	.004	.008	.035	.090	.245	.462
5	.006	.012	.054	.141	.382	.723
6	.009	.017	.078	.204	.550	1.04
7	.012	.023	.106	.277	.749	1.42
8	.016	.030	.138	.362	.978	1.85
10	.025	.047	.216	.565	1.53	2.89
15	.056	.105	.486	1.27	3.44	6.50
20	.099	.186	.863	2.26	4.85	11.56
25	.155	.291	1 35	4.45	9.55	18.06
30	.224	.419	1.94	5.09	13.75	26.01
40	.398	.745	3.45	9.04	24.45	46.23
50	.621	1.17	5.40	14.13	38.20	73.93
75	1.40	2 62	12.14	31.79	85.95	162.5
100	2.48	4.66	21.58	56.52	152.8	289.0
150	5.59	10.48	48.57	127.2	343.7	650.2
200	9.94	18.63	86.32	226.1	611.1	1156.
300	22.36	41.92	194.20	508.7	1092.	2601.

ADDITIONAL HEAD NECESSARY TO OVERCOME THE RESISTANCE OF ONE CIRCULAR BEND.

Question: The radius of the pipe being to the radius of the bend in the ratio of 1 : 5, the number of

degrees in the bend being 90°, and the velocity 75 feet per second, what is the additional head required to overcome the resistance of the bend ?

Answer: In this table, in first column, headed "Velocity per Second," find 75 feet, opposite which, in column headed "1 : 5, 90°," is found 6.03 feet, the required head.

Question: The radius of the pipe being to the radius of the bend in the ratio of 2 : 5, the number of degrees in the bend being 120°, and the velocity per second 100 feet, what is the additional head required to overcome the resistance of one bend ?

Answer: In this table, opposite 100 feet velocity, will be found in column headed "2 : 5, 120°," the required number, viz., 21.34 feet.

TABLE SHOWING ADDITIONAL HEAD REQUIRED TO OVERCOME THE RESISTANCE OF ONE CIRCULAR BEND.

Velocity per Second	Ratio of Radius of Pipe to Radius of Bend.									
Feet.	1 : 5 30° Head. Feet.	1 : 5 60° Head. Feet.	1 : 5 90° Head. Feet.	1 : 5 120° Head. Feet.	1 : 5 180° Head. Feet.	2 : 5 30° Head. Feet.	2 : 5 60° Head. Feet.	2 : 5 90° Head. Feet.	2 : 5 120° Head. Feet.	2 : 5 180° Head. Feet.
1	.0004	.0007	.0011	.0014	.0022	.0005	.001	.002	.002	.005
2	.0014	.0029	.0043	.0058	.0086	.0021	.004	.006	.008	.013
3	.0032	.0064	.0096	.0128	.0192	.0048	.010	.014	.020	.029
4	.0057	.0114	.0171	.0228	.0342	.0085	.017	.025	.034	.051
5	.0089	.0179	.0268	.0358	.0536	.0133	.027	.040	.054	.080
6	.0129	.0257	.0386	.0514	.0772	.0192	.038	.058	.076	.115
7	.0175	.0350	.0525	.0700	.1050	.0261	.052	.078	.104	.157
8	.0229	.0457	.0686	.0914	.1372	.0341	.068	.102	.136	.205
10	.0357	.0714	.1072	.1428	.2144	.0533	.107	.160	.214	.320
15	.0804	.1607	.2411	.3214	.4822	.1200	.240	.360	.480	.720
20	.1429	.2858	.4287	.5716	.8574	.2130	.426	.639	.852	1.28
25	.2232	.4464	.6696	.8928	1.34	.3333	.667	1.00	1.33	2.00
30	.3214	.6428	.9642	1.29	1.93	.4798	.960	1.44	1.92	2.88
40	.5714	1.14	1.71	2.28	3.42	.8530	1.71	2.56	3.42	5.12
50	.8927	1.79	2.68	3.58	5.36	1.33	2.66	3.99	5.32	7.98
75	2.01	4.02	6.03	8.04	12.06	3.00	6.00	9.00	12.00	18.00
100	3.57	7.14	10.71	14.28	21.42	5 33	10.67	15.99	21.34	31.98
150	8.04	16.07	24.11	32.14	48.22	12.00	24.00	36.00	48.00	72.00
200	14.29	28.58	42.87	57.16	85.74	21.32	42.64	63.96	127.92	127.92
300	32.14	64.28	96.42	128.56	192.84	47.98	95.96	143.24	287.88	287.88

FLOW OF WATER IN OPEN CHANNELS.

Question: The dimensions of a canal being, top width 11 feet, bottom width 5 feet, depth 4 feet, and the fall per mile 8 feet. Required the number of inches, miners' measure, that it will carry.

Answer: In this table, in column headed "Fall per Mile," find 8 feet, opposite which in column headed with given specifications (11, 5, 4) is found 104.8 cubic feet, the flow per second. This multiplied by 50, the number of miners' inches equal to one cubic foot flow per second, gives 104.8 × 50 = 5240 miners' inches required.

TABLE SHOWING FLOW OF WATER IN OPEN CHANNELS, BAS TO PERPENDICULAR OF THE SIDE SLOPES BEING AS 3:4.

Fall per Mile. Ft.	Fall per Rod. In.	T 2.2 ft. B 1.0 ft. D .8 ft. Section 1.28 sq. ft. Cu. Ft.	T 3.3 ft. B 1.5 ft. D 1.2 ft. Section 2.88 sq. ft. Cu. Ft.	T 4.4 ft. B 2.0 ft. D 1.6 ft. Section 5.12 sq. ft. Cu. Ft.	T 5.5 ft. B 2.5 ft. D 2.0 ft. Section 8.0 sq. ft. Cu. Ft.	T 6.6 ft. B 3.0 ft. D 2.4 ft. Section 11.52 sq. ft. Cu. Ft.	T 7.7 ft. B 3.5 ft. D 2.8 ft. Section 15.68 sq. ft. Cu. Ft.	T 8.8 ft. B 4.0 ft. D 3.2 ft. Section 20.48 sq. ft. Cu. Ft.
1	.0375	.45	1.33	2.67	5.57	9.05	13.46	20.26
2	.0750	.63	1.88	3.87	7.88	12.80	19.04	28.64
3	.1125	.77	2.30	4.74	9.65	15.67	23.32	35.08
4	.1500	.89	2.65	5.47	11.14	18.52	26.93	40.51
5	.1875	1.00	2.97	6.12	12.46	20.24	30.11	45.30
6	.2250	1.09	3.25	6.70	13.65	22.17	32.98	49.62
7	.2625	1.18	3.42	7.24	14.74	23.94	35.63	53.58
8	.3000	1.26	3.75	7.73	15.75	25.60	38.08	57.28
9	.3375	1.34	3.98	8.21	16.71	27.15	40.39	60.76
10	.3750	1.41	4.19	8.65	17.61	28.62	42.57	64.05
11	.4125	1.48	4.40	9.07	18.47	30.02	44.55	67.18
12	.4500	1.54	4.60	9.48	19.30	31.35	46.64	70.65
13	.4875	1.61	4.78	9.86	20.08	32.63	48.54	73.03
14	.5250	1.67	4.96	10.24	20.84	33.87	50.38	75.79
15	.5625	1.73	5.14	10.60	21.57	35.05	52.14	78.44
16	.6000	1.78	5.31	10.94	22.27	36.20	53.86	81.02
17	.6375	1.84	5.47	11.28	22.96	37.31	55.51	83.51
18	.6750	1.89	5.63	11.60	23.63	38.39	57.11	85.93
19	.7125	1.94	5.78	11.92	24.28	39.44	58.58	88.29
20	.7500	1.99	5.93	12.23	24.91	40.47	60.21	90.58
21	.7875	2.04	6.08	12.54	25.53	41.47	61.70	92.82
22	.8250	2.09	6.22	12.83	26.12	42.45	63.15	95.00
23	.8625	2.14	6.36	13.12	26.71	43.40	64.57	97.15
24	.9000	2.18	6.50	13.40	27.29	44.34	65.95	99.23
25	.9375	2.23	6.63	13.68	27.98	45.24	67.32	101.28

In Tables, T signifies top width; B, bottom width; D, depth.

TABLE SHOWING FLOW OF WATER IN OPEN CHANNELS, BASE TO PERPENDICULAR OF THE SIDE SLOPES BEING AS 3 : 4.—(*continued.*)

Fall per Mile Ft.	Fall per Rod. In.	T 9.9 ft. B 4.5 ft. D 3.6 ft. Section 25.92 sq ft. Cu. Ft.	T 11 ft. B 5 ft D 4 ft. Section 32 sq. ft. Cu. Ft.	T 13.2 ft. B 6.0 ft. D 4.8 ft. Section 46.09 sq. ft. Cu. Ft.	T 16.4 ft. B 7.0 ft. D 5.6 ft. Section 62.72 sq. ft. Cu. Ft.	T 17.6 ft. B 8.0 ft. D 6.4 ft. Section 81.92 sq. ft. Cu. Ft.	T 19.8 ft. B 9.0 ft. D 7.2 ft. Section 103 68 sq. in. Cu. Ft.	T 22 ft. B 10 ft. D 8 ft. Section 128 sq. ft. Cu. Ft.
1	.0375	28.04	37.1	58.4	96.5	138.3	189.2	261.2
2	.0750	39.67	52.4	82.7	136.4	195.7	267.6	369.4
3	.1125	48 59	64.2	101.4	167.1	239.6	327.7	451.3
4	.1500	56.10	74.1	117.1	192.9	276.7	378.4	522.3
5	.1875	62.71	82.9	130.9	215.7	309.3	423.1	584.0
6	.2250	68.70	90.8	143.4	236.3	338.8	463.5	639.8
7	.2625	74.19	98.1	154.8	255.3	366.0	500.5	691.0
8	.3000	79.53	104.8	165.5	272.9	391.2	535.1	738.7
9	.3375	84.14	111.1	175.6	289.4	415.0	567.6	783.5
10	.3750	88.68	117.1	185.1	305.0	437.4	598.2	825.9
11	.4125	93.02	122.9	194.1	319.9	458.7	613.2	866.2
12	.4500	97.15	128 4	202.8	334.2	479.1	655.4	925.6
13	.4875	101.13	133 6	211.1	347.8	498.7	682.1	941.7
14	.5250	104.94	138.7	219.0	360.9	517.5	707.8	977.2
15	.5625	108.63	143.5	226.6	373.6	535.7	732.8	1011.5
16	.6000	112.18	148.2	234.1	385.9	553.3	756.7	1044.7
17	.6375	115.64	152.4	241.3	397.8	570.3	780.1	1076.9
18	.6750	118.99	157.2	248.3	409.3	586.9	802.7	1108.1
19	.7125	122.26	161.5	255.1	420.5	601.5	824.8	1138.4
20	.7500	125.43	165.7	261.7	431.4	618.5	846.1	1168.0
21	.7875	128.53	169.8	268.2	442.0	633.9	867.0	1196.8
22	.8250	131.55	173.8	274.5	452.5	648.8	887 4	1225.0
23	.8625	134.51	177.7	280.7	462.9	663.4	907.4	1252.6
24	.9000	137.40	181.5	286.7	472.6	677.7	926.0	1279.5
25	.9375	140.24	185.3	292.6	482.3	691.6	946.0	1306.0

In Tables, T signifies top width; B, bottom width; D, depth.

FLOW OF WATER IN OPEN CHANNELS—(*Continued.*)

Question: Required the number of cubic feet of water that will flow in a canal whose top width is 40 feet, bottom width 20 feet, depth 5 feet, and whose fall is 2 feet per mile.

Answer: In this table, in column "Fall per Mile," find 2 feet, opposite which in column headed with the given specifications (40, 20, 5) is found the required flow, viz., 376.1 cubic feet.

TABLE SHOWING FLOW OF WATER IN OPEN CHANNELS, BASE TO PERPENDICULAR OF THE SIDE SLOPES BEING AS 2 : 1.

Fall per Mile. Feet.	Fall per Rod. Feet.	T 6 ft. B 2 ft. D 1 ft. Section 4 sq. ft. Cu. Ft.	T 9 ft. B 3 ft. D 1.5 ft. Section 9 sq. ft. Cu. Ft.	T 12 ft. B 4 ft. D 2 ft. Section 16 sq. ft. Cu. Ft.	T 16 ft. B 6 ft. D 2.5 ft. Section 27.5 sq. ft. Cu. Ft.	T 22 ft. B 10 ft. D 3 ft. Section 48 sq. ft. Cu. Ft.	T 28 ft. B 12 ft. D 4 ft. Section 30 sq. ft. Cu. Ft.	T 40 ft. B 20 ft. D 5 ft. Section 150 sq. ft. Cu. Ft.
.5	.01875	1.27	3.85	8.63	18.11	8.79	78.2	188.1
.6667	.0250	1.46	4.44	9.96	20.91	44.79	90 3	217.2
.8333	.03125	1.63	4.96	11.14	23.38	50.08	101.0	242.8
1	.0375	1.79	5.44	12.20	25.61	54.86	110.6	266.0
1.25	.046875	2.00	6.08	13.64	28.68	61.32	123.7	297.4
1.5	.05625	2.19	6.67	14.96	31.34	67.26	135 7	326.1
1.75	.065625	2.37	7.19	16.14	33.88	72 57	146.4	351.8
2	.0750	2.53	7.69	17.26	36.22	77.58	156.5	376.1
2.25	.084375	2.68	8.16	18.30	38.42	82.29	165.9	399.0
2.5	.09375	2.83	8.60	19 29	40.50	86.72	174.9	420.6
3	.1125	3.10	9.42	21.14	44.36	95.00	191.6	460.7
3.5	.13125	3.35	10.17	22.83	47.91	102.6	207.0	497.6
4	.1500	3.58	10.87	24.41	51.22	109.7	221.3	531.9
4.5	.16875	3.79	11.54	25.88	54.33	116.3	234.7	564.2
5	.1875	4.00	12.16	27.29	57.27	122.7	247.4	594.8
6	.2250	4.38	13.31	29.89	62.74	134.4	271.0	651.5
7	.2625	4.73	14.39	32.29	67.79	145.1	292.7	703.6
8	.3000	5.06	15.38	34.52	72.43	155.2	312.9	752.2
9	.3375	5.37	16.31	36.61	76.83	164.6	331.9	797.9
10	.3750	5.66	17.19	38.59	80.99	173.5	349.9	841 1
11	.4125	5.93	18.03	40.47	84.94	181.9	366.9	882.1
12	.4500	6.20	18.74	42.27	88.72	190.1	383.2	921.5

In Tables, T signifies top width; B, bottom width; D, depth.

RELATIVE CARRYING CAPACITY OF OPEN CHANNELS WHOSE SECTIONAL AREAS ARE EQUAL TO EACH OTHER BUT OF DIFFERENT FORMS.

The form in which the bottom width is made equal to one of the sides, and in which the base to the perpendicular of the side slope is as 3 : 4, has been adopted as the standard form when the ground will admit, it being the simplest of construction.

The relative carrying capacity for trapezoidal form—Base : depth of slope : : 3 : 4; bottom width : depth : : 5 : 4. Coefficient of capacity, 1000.

Trapezoidal form—Base : depth of slope : : 1 : 1; bottom width = depth, .994.

Coefficients: flume, 2 : 1, .961; semi-hexagonal, 1.008; square, .925; semicircular, 1.056.

Question: The fall being 6 feet per mile, the sectional area of a *square flume* 8 square feet, what will be its carrying capacity per second?

Answer: In table showing Flow of Water in Open Channels—Base to Perpendicular of Side Slopes being as 3 : 4, in column of "Fall per Mile," find the given fall 6 feet, opposite which in column headed "sectn. 8.0 sq. ft." is found 13.65 cubic feet. This multiplied by the coefficient for a square, viz., .925, gives $13.64 \times .925 = 12.63$ cubic feet.

Remarks.—The tables for the flow of water in open

channels have been computed upon the assumption that the canals are smooth and straight.

FLOW OF WATER THROUGH NOZZLES.

Question: The head being 125 feet, how many cubic feet per second will a nozzle 4 inches in diameter discharge? How many miners' inches?

Answer: In this table find in the first column the given head 125 feet, opposite which in column headed "four inches" will be found the required quantity, viz., 7.28 cubic feet $\times$ 50 = 364 *miners' inches.*

Question: Between the inlet and the nozzles of a hydraulic pipe 3 feet in diameter the distance is five miles and the total fall 275 feet. The pipe is to carry 2000 miners' inches of water, which is to be discharged through two "Little Giants," or nozzles equal in size. What will be the loss of head by the resistance in the main pipe? What will be the size of each nozzle?

Answer: In table showing Flow of Water through Clean Iron Pipes find in column headed 36 Inches that number which multiplied by 50 will make 2000, the given number of *miners' inches.* In this case 40.86 approximates sufficiently near, opposite which in column headed "Fall per Mile" is found 14.78 feet, the loss of head per mile. Multiply this by 5, the length of the pipe, and we have 14.78 $\times$ 5 = 73.9

feet, the loss of resistance in the pipe 5 miles long. Subtracting this from the total head, $275 - 73.9 = 201.1$ feet remaining head. Again, in the table find 200 nearest 201.1 feet in column headed "Head," opposite which in column headed "6 inches" is found 20.64, which multiplied by 50 gives 1.032, or approximately 1000 miners' inches, which each nozzle is required to discharge. Hence the nozzles are to be 6 inches in diameter each.

TABLE SHOWING FLOW OF WATER THROUGH NOZZLES—QUANTITY AND HORSE-POWER.

Head	Velocity per Sec.	50 Min. Inch. 1 Cubic Foot.	100 Min. Inch. 2 Cubic Feet.	Diameters of Nozzles.							
				1 Inch.		1.5 Inches.		2 Inches.		2.5 Inches.	
Feet.	Feet.	H.P.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.
1	8.025	.106	.212	.041	.0046	.093	.010	.164	.018	.255	.029
1.5	9.83	.158	.316	.050	.0085	.111	019	.200	.034	.312	.053
2	11.35	.211	.422	.058	.013	.130	.029	.232	.052	.360	.082
2.5	12.68	.264	.528	.064	.018	.145	.041	.256	.072	.402	.114
3	13.90	.317	.634	.061	.024	.159	.054	.284	.096	.440	.150
3.5	15.01	.370	.740	.016	.030	.171	.068	.304	.120	.475	.189
4	16.05	.421	.842	.081	.03	.183	.083	.324	.148	.507	.231
4.5	17.02	.474	.948	.086	.044	.194	.099	.344	.176	.540	.275
5	17.95	.528	1.06	.091	.051	.205	.113	.364	.204	.56	.315
6	19.66	.634	1.27	.100	.068	.224	.153	.400	.272	.622	.425
7	21.23	.739	1.48	.108	.086	.242	.193	.432	.344	.672	.535
7.5	21.98	.702	1.58	.111	.095	.250	.214	.444	.380	.697	.595
10	25.38	1.06	2.12	.129	.146	.290	.329	.516	.584	.805	.915
12.5	28.37	1.32	2.64	.144	.204	.324	.46	.566	.816	.897	1.28
15	31.08	1.59	3.18	.158	.269	.355	.505	.632	1.08	.985	1.68
17.5	33.57	1.85	3.70	.170	.339	.383	.782	.680	1.36	1.06	2.11
20	35.89	2.11	4.22	.182	.414	.410	.931	.728	1.66	1.14	2.58
22.5	38.07	2.38	4.76	.193	.494	.435	1.11	.772	1.98	1.21	3.08
25	40.13	2.64	5.28	.204	.578	.458	1.30	.816	2.31	1.27	3.61
27.5	42.08	2.90	5.80	.213	.660	.480	1.50	.852	2.60	1.33	4.17
30	43.95	3.02	6.04	.228	.760	.513	1.71	.912	3.04	1.42	4.75
32.5	45.75	3.34	6.68	.232	.857	.522	1.93	.928	3.43	1.45	5.35
35	47.47	3.69	7.38	.241	.958	.542	2.15	.964	3.83	1.51	5.98
40	50.75	4.22	8.44	.257	1.17	.579	2.63	1.03	4.68	1.61	7.31
45	53.83	4.75	9.50	.273	1.40	.614	3.14	1.09	5.60	1.71	8.23
50	56.75	5.28	10.56	.288	1.64	.648	3.68	1.15	6.56	1.79	10.22
60	62.16	6.34	12.68	.385	2.15	.709	4.84	1.26	8.60	1.97	13.43
70	67.14	7.39	14.78	.341	2.71	.766	6.10	1.36	10.84	2.13	16.93
80	71.78	8.46	16.90	.364	3.31	.819	7.45	1.46	13.24	2.27	20.69
90	76.13	9.53	19.06	.386	3.95	.864	8.88	1.54	15.80	2.44	24.68
100	80.25	10.56	21.12	.407	4.63	.916	10.41	1.63	18.52	2.54	28.90
125	89.72	13.21	26.42	.455	6.47	1.02	14.55	1.82	25.88	2.81	40.40
150	98.28	15.85	31.70	.499	8.50	1.12	19.12	2.00	34.00	3.11	53.12
175	106.1	18.50	37.00	.539	10.70	1.21	24.07	2.16	42.80	3 36	66.86
200	113.5	21.14	42.28	.576	13.1	1.29	29.43	2 30	52.4	3.50	81.75
250	127.1	26.62	52.84	.644	18.3	1.45	41.13	2.58	73.2	4.02	114.2
300	139.0	31.70	63.40	.705	24.0	1.59	54.07	2.82	96.0	4.40	150.2
350	150.1	37.08	74.16	.762	30.3	1.71	68.15	3.05	121.2	4.76	189.3
400	160.5	42.27	84.54	.814	37.0	1.83	83.25	3.26	148.0	5.09	231.2
450	170.2	47.64	95.28	.864	44.2	1.94	99.34	3 46	176.8	5 40	276.0
500	179 4	52.84	105.7	.910	51.7	2.05	116.5	3.64	206.8	5.60	323.2
550	188.2	58.22	116.4	.955	59.7	2.10	134.2	3.82	238.8	5.96	372.7
600	196.6	63.41	126.8	.999	68.0	2.23	152.9	3.99	272.0	6.23	475.0
700	212.3	73.98	148.0	1.06	85.7	2.46	192.8	4.36	342.8	6.79	535.5
800	226.9	84.55	169.1	1.15	104.7	2.58	235.5	4.60	418.8	7.19	654.0
900	240.7	95.14	190.3	1.22	124.9	2.75	281.0	4.88	499.6	7.63	780.5
1000	253.8	105.6	211.2	1.29	146.2	2.89	329.0	5.16	584.8	8 04	914.0

TABLE SHOWING FLOW OF WATER THROUGH NOZZLES—QUANTITY AND HORSE-POWER—(*continued.*)

Head	Velocity per Sec.	150 Min. Inch. 3 Cubic Feet.	200 Min. Inch. 4 Cubic Feet.	Diameters of Nozzles.							
				3 Inches.		3.5 Inches.		4 Inches.		4.5 Inches.	
Feet.	Feet.	H.P.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet	H.P.	Cubic Feet.	H.P.
1	8.025	.308	.424	.372	.040	.50	.056	.656	.072	.81	.090
1.5	9.83	.474	.632	.444	.076	.61	.105	.800	.136	1.00	.171
2	11.35	.633	.844	.520	.116	.70	.160	.928	.208	1.17	.260
2.5	12.68	.792	1.06	.58	.164	.79	.224	1.02	.288	1.30	.370
3	13.90	.951	1.27	.636	.216	.86	.295	1.14	.384	1.43	4.85
3.5	15.01	1.110	1.48	.684	.272	.94	.370	1.22	.480	1.54	.612
4	16.05	1.26	1.68	.742	.332	1.02	.452	1.30	.592	1.64	.742
4.5	17.02	1.42	1.90	.776	.396	1.06	.540	1.38	.704	1 74	.815
5	17.95	1.58	2.12	.820	.452	1.11	.600	1.46	.816	1.84	1.02
6	19.66	1.90	2.54	.896	.612	1.22	.833	1.60	1.09	2.01	1.38
7	21.23	2.22	2.96	.968	.772	1.32	1.05	1.73	1.38	2.18	1.74
7.5	21.98	2.38	3.16	1.00	.856	1.36	1.16	1.78	1.52	2.25	1.92
10	25.38	3.18	4.24	1.16	1.32	1.57	1.79	2.16	2.34	2.61	2.97
12.5	28.37	3.96	5.28	1.30	1.84	1.76	2.50	2.30	3.46	2.92	4.14
15	31.08	4 77	6.36	1.42	2.42	1.93	3.29	2.53	4.32	3.19	5.44
17.5	33.57	5.55	7.40	1.53	3.13	2.08	4.20	2.72	5.44	3.44	7.04
20	35.89	6.33	8.44	1.64	3.72	2.23	5.07	2.91	6.64	3.69	8.37
22.5	38.07	7.14	9.52	1.74	4.44	2.36	6.05	3.09	7.92	3.91	9.99
25	40.13	7.92	10.56	1.83	5.20	2.54	7.08	3.26	9.24	4.12	11.70
27.5	42.08	8.70	11.60	1.92	6.00	2.61	8.17	3.41	10.68	4.32	13.50
30	43.95	9.06	12.08	2.05	6.84	2.79	9.31	3.65	12.16	4.61	15.39
32.5	45.75	10.02	13.36	2.09	7.72	2.84	10.50	3.71	13.72	4.70	17.37
35	47.47	11.07	14.76	2.17	8.60	2.95	11.71	3.86	15.32	4.88	19.35
40	50.75	12.66	16.88	2.32	10.52	3.15	14.33	4.12	18.72	5.22	23.67
45	53.83	14.25	19.00	2.46	12.56	3.34	17.10	4.36	22.40	5.54	28.25
50	56.75	15.84	21.12	2.59	14.72	3.52	20.03	4.60	26.24	5.83	32.12
60	62.10	19.20	25.36	2.84	19.36	3.86	26.32	5.04	34.40	6.39	43.55
70	67.14	22.17	29.56	3.06	24.40	4.17	33.17	5.42	43.36	6.84	54.90
80	71.78	25.36	33.86	3.28	20.80	4.40	40.55	5.81	52.96	7.38	67.05
90	76.13	28.59	38.12	3.46	35.52	4.73	48.37	6.16	68.20	7.78	79.92
100	80.25	31.68	42.24	3.66	41.64	4.98	56.67	6.52	74.08	8.23	93.70
125	89.72	39.63	52.84	4.08	58.20	5.57	79.20	7.28	103.5	9.18	130.9
150	98.28	47 55	63.40	4.48	76.48	6.10	104.10	8.00	136.0	10.08	172.1
175	106.1	55.50	74.00	4.84	96.28	6.60	131.07	8.04	171.2	10.89	216.6
200	113.5	63.42	84.56	5.10	117.7	7.05	160.22	9.20	219.6	11.61	261.7
250	127.1	7[illegible].26	105.7	5.80	164.5	7.88	223.92	10.32	292.8	13.05	370.2
300	139.0	95.10	126.8	6.36	216.3	8.63	294.3	11.28	384.0	14.31	486.9
350	150.1	111.2	148.3	6.84	272.6	9.33	371.2	12.20	484.8	15.39	613.2
400	160.5	126.8	169.1	7.32	323.0	9.97	453.2	13.04	592.0	16.47	749.2
450	170.2	142.9	190.6	7.76	397.4	10.58	541.0	13.84	707.2	17.46	894.2
500	179.4	158.5	211.4	8.20	406.0	11.15	627.0	14.56	827.2	18.45	104.8
550	188.2	174.7	232.8	8 40	536 8	11.69	731.0	15.28	955.2	18.90	1208
600	196.6	190.2	253.6	8.92	611.0	12.21	832.7	15.96	1080.0	20.07	1376
700	212.3	221.9	296.0	9.84	771.2	13.31	1051	17.44	1371.2	22.14	1735
800	226.9	253.6	338.2	10.32	942.0	14.10	1282	18.40	1675.2	23.22	2119
900	240.7	285.4	380.6	11.00	1124	14.9	1530	19.52	1998.4	24.75	2529
1000	253.8	316.8	422.4	11.56	1316	15.76	1791	30.64	2339.2	26.00	2961

TABLE SHOWING FLOW OF WATER THROUGH NOZZLES—QUANTITY AND HORSE-POWER—(*continued.*)

Head	Velocity per Sec.	300 Min. Inch. 6 Cubic Feet.	400 Min. Inch 8 Cubic Feet.	Diameters of Nozzles.							
				5 Inches.		5.5 Inches.		6 Inches.		7 Inches.	
Feet.	Feet.	H.P.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.
1	8.025	.616	8.8	1.02	.116	1.23	.140	1.49	.100	1.99	.226
1.5	9.83	.948	1.26	1.25	.212	1.51	.257	1.78	.304	2.44	.420
2	11.35	1.27	1.69	1.44	.327	1.74	.395	2.08	.464	2.82	.641
2.5	12.68	1.58	2.11	1.61	.457	1.95	.553	2.32	.656	3.15	.896
3	13.90	1.90	2.54	1.76	.601	2.13	.727	2.54	.864	3.45	1.18
3.5	15.01	2.22	2.96	1.90	.757	2.31	.916	2.74	1.09	3.78	1.48
4	16.05	2.53	3.37	2.03	.925	2.46	1.12	2.97	1.33	4.09	1.81
4.5	17.02	2.84	3.79	2.16	1.10	2.51	1.33	3.10	1.58	4.23	2.16
5	17.95	3.18	4.24	2.27	1.26	2.75	1.53	3.28	1.81	4.40	2.48
6	19.66	3.81	5.08	2.49	1.70	3.02	2.05	3.58	2.45	4.88	3.33
7	21.23	4.44	5.92	2.69	2.14	3.26	2.59	3.87	3.09	5.28	4.20
7.5	21.98	4.74	6.32	2.79	2.38	3.42	2.87	4.00	3.42	5.40	4.66
10	25.38	6.36	8.48	3.22	3.66	3.89	4.42	4.64	5.28	6.30	7.16
12.5	28.37	7.92	10.56	3.59	5.11	4.3	6.18	5.20	7.36	7.05	10.02
15	31.08	9.54	12.72	3.94	6.72	4 76	8.13	5.68	8.08	7.72	13.17
17.5	33.57	11.10	14.80	4.26	8.46	5.15	10.24	6.12	12.52	8.34	16.80
20	35.80	12.66	16.88	4.55	10.34	5.50	12.51	6.56	14.88	8.92	20.28
22.5	38.07	14.28	19.04	4.83	12.34	5.84	14.93	6.96	17.76	9.46	24.20
25	40.13	15.84	21.12	5.09	14.45	6.16	17.49	7.32	20.80	10.15	28.33
27.5	42 08	17.40	23.20	5.34	16.67	6.46	20.18	7.68	24.00	10.40	32.08
30	43.95	18.12	24.16	5.70	19.00	6.90	22.99	8.20	27.36	11.18	37.25
32.5	45.75	20.04	26.72	5.80	21.42	7.02	25.92	8.36	30.88	11.37	41.99
35	47.47	22.14	29.52	6.02	23.94	7.28	28.97	8.68	33.40	11.80	46.84
40	50.75	25.32	33.76	6.44	29 25	7.78	83.39	9.28	42.08	12.61	57.33
45	53.83	29.50	38.00	6.82	34.90	8.26	42.23	9.84	50.24	13.38	68.40
50	56.75	31.68	42.24	7.19	40.87	8.70	49.46	10.36	58.88	14.10	80.11
60	62.16	38.04	50.72	7.88	53.72	9.54	65.01	11.36	77.44	15.44	105.3
70	67 14	44.34	59.12	8.51	67.72	10.30	81.95	12.24	97.60	16.09	132.7
80	71.78	50.74	67.64	9.10	82.76	11.01	100.1	13.12	119.2	17.84	162.2
90	76.13	57.18	76.24	9.65	98.72	11.58	119.5	13.84	142.1	18.92	193.5
100	80.25	63.36	84.48	10.17	115.6	12 31	139.9	14.64	166.6	19.94	226.7
125	89.72	79.26	95.68	11.38	161.6	13.76	195.0	16.32	232.8	22.30	316.8
150	98.28	95.10	126.8	12.46	212.5	15.08	257.0	17.92	305.9	24.42	416.4
175	106.1	111.0	148.0	13.46	267.5	15.29	313.7	19.36	385.1	26.39	524.3
200	113.5	126.8	169.1	14.34	327.0	17.51	395.7	20.64	470.8	28.20	640.9
250	127.1	158.5	211.4	16.09	457.0	19.47	553.0	23.20	658.0	31.54	8[illegible]5.7
300	139.0	190.2	253.6	17.62	601.0	21.33	726.9	25.44	865.2	34.54	1177
350	150.1	222.5	296.6	19.04	757.2	22.04	916.3	27.36	1090.4	37.32	1485
400	160.5	253.6	338.2	20.35	925.0	24.62	1179	29.28	1332	29 89	1813
450	170.2	285.8	381.1	21.59	1104	26.12	1335	31.04	1590	42.31	2164
500	179.4	317.1	422.8	22.75	1293	27.54	1565	32.80	1864	44.00	2508
550	188 2	349.2	465.6	23.86	1491	28.88	1805	33.60	2147	46.78	2923
600	196.0	380.4	507.2	24.93	1699	30.16	2056	35 08	2446	48.86	3331
700	212.3	444.0	592 0	27.18	2142	32.88	2591	39.36	3085	53.26	4203
800	226.9	507.3	676.4	28.77	2616	34.92	3166	41.28	3768	56.40	5129
900	240.7	570.9	761.2	30.52	3122	36.94	3778	44.00	4496	59.83	6120
1000	253.8	633.6	844.8	32.17	3656	38.93	4424	46.24	5264	63.06	7166

TABLE SHOWING FLOW OF WATER THROUGH NOZZLES—QUANTITY AND HORSE-POWER.

Head	Velocity per Sec.	500 Min. Inches. 10 Cubic Feet.	1000 Min. Inches. 20 Cubic Feet.	Diameters of Nozzles.							
				8 Inches.		9 Inches.		10 Inches.		12 Inches.	
Feet.	Feet.	H.P.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.
1	8.025	1.06	2.12	2.62	.288	3.35	.360	4.07	.46	5.96	.904
1.5	9.83	1.58	3.16	3.20	.544	3.99	.684	4.99	.85	7.12	1.68
2	11.35	2.11	4.22	3.71	.832	4.68	1.04	5.76	1.3	8.32	2.56
2.5	12.68	2.64	5.28	4.08	1.15	5.22	1.48	6.44	1.83	9.28	3.58
3	13.90	3.17	6.34	4.56	1.54	5.72	1.94	7.05	2.40	10.16	4.72
3.5	15.01	3.70	7.40	4.88	1.92	6.16	2.45	7.62	3.03	10.96	5.92
4	16.05	4.21	8.42	5.20	2.37	6.58	2.99	8.14	3.70	11.88	7.24
4.5	17.02	4.74	9.48	5.52	2.81	6.98	3.26	8.64	4.42	12.40	8.64
5	17.95	5.28	10.6	5.84	3.26	7.38	4.07	9.10	5.05	13.12	9.92
6	19.66	6.34	12.7	6.40	4.36	8.06	5.51	9.97	6.80	14.32	13.32
7	21.23	7.39	14.8	6.92	5.52	8.71	6.95	10.77	8.57	15.48	16.80
7.5	21.98	7.92	15.8	7.12	6.08	9.00	7.70	11.14	9.50	16.00	18.64
10	25.38	10.6	21.2	8.64	9.36	10.41	11.88	12.87	14.63	18.56	28.64
12.5	28.37	13.2	26.4	9.20	13.84	11.70	16.56	14.39	20.44	20.80	40.08
15	31.08	15.9	31.8	10.12	17.28	12.78	21.78	15.76	26.87	22.72	52.68
17.5	33.57	18.5	37.0	10.88	21.76	13.77	28.17	17.03	33.86	24.48	67.20
20	35.89	21.1	42.2	11.64	26.56	14.76	33.48	18.20	41.37	26.24	81.12
22.5	38.07	23.8	47.6	12.36	31.68	15.66	39.96	19.31	49.37	27.84	96.80
25	40.13	26.4	52.8	13.04	36.96	16.47	46.80	20.35	57.82	29.28	113.3
27.5	42.08	29.0	58.0	13.64	42.72	17.28	54.00	21.34	66.70	30.72	130.7
30	43.95	30.2	60.4	14.60	48.64	18.45	61.56	22.81	76.01	32.80	149.0
32.5	45.75	33.4	66.8	14.84	54.88	18.81	69.48	23.20	85.70	33.44	168.9
35	47.47	36.9	73.8	15.44	61.28	19.53	77.40	24.08	95.78	34.72	187.4
40	50.75	42.2	84.4	16.48	74.88	20.88	94.68	25.74	117.0	37.12	229.3
45	53.83	47.5	95.0	17.44	89.60	22.14	113.0	27.30	139.6	39.36	273.6
50	56.75	52.8	105.6	18.40	105.0	23.31	128.5	28.78	163.5	41.44	320.4
60	62.16	63.4	126.8	20.16	137.6	25.56	174.2	31.53	214.9	45.44	421.2
70	67.14	73.9	147.8	21.68	173.4	27.54	219.6	34.06	270.9	48.96	530.8
80	71.78	84.6	169.0	23.36	211.8	29.52	268.2	36.41	331.0	52.48	648.8
90	76.13	95.3	190.6	24.64	252.8	31.14	319.7	38.61	394.9	55.36	774.0
100	80.25	106.6	211.2	26.08	296.3	32.94	374.8	40.70	462.5	58.56	906.8
125	89.72	132.1	264.2	29.12	414.0	36.72	523.8	45.51	646.5	65.28	1267
150	98.28	158.5	317.0	32.00	554.0	40.32	688.3	49.85	849.8	71.68	1666
175	106.1	185.0	370.0	34.56	684.8	43.56	866.5	53.85	1070	77.44	2097
200	113.5	211.4	422.8	36.80	878.4	46.44	1059	57.56	1308	82.56	2564
250	127.1	264.2	528.4	41.28	1171	52.20	1481	64.36	1828	92.80	3583
300	139.0	317.0	634.0	45.12	1536	57.24	1947	70.50	2403	101.76	4708
350	150.1	370.8	741.6	48.80	1949	61.56	2453	76.15	3029	109.4	5940
400	160.5	422.7	845.4	52.16	2368	65.88	2997	81.41	3700	117.1	7252
450	170.2	476.4	952.8	55.36	2829	69.84	3577	86.35	4415	124.2	8656
500	179.4	528.4	1057	58.24	3409	73.80	4194	91.02	5172	131.2	10032
550	188.2	582.2	1164	61.12	3821	75.60	4831	95.46	5966	134.4	11692
600	196.6	634.1	1268	63.84	4352	80.28	5504	99.71	6798	142.7	13324
700	212.3	739.8	1480	69.76	5485	88.56	6191	108.7	8567	157.4	16812
800	226.9	845.5	1691	73.60	6701	92.88	8478	115.1	10468	165.1	20516
900	240.7	951.4	1903	78.08	7994	99.00	10116	122.5	12489	176.0	24480
1000	253.8	1056	2112	82.56	9357	104.0	11844	128.7	14624	185.0	28664

EXPLANATION OF PIPE TABLES.

The tables for sheet-iron pipe are arranged as follows:

COLUMN NO. 1 gives the diameter of the pipe in inches.

COLUMN NO. 2 is the area in square inches corresponding to the diameter.

COLUMN NO. 3 is the thickness of the iron or steel in decimal parts of an inch.

COLUMN NO. 4 is the thickness of the iron or steel by the Birmingham wire gauge.

COLUMN NO. 5 is the working pressure the pipe will be subjected to in pounds per square inch, allow- 10,000 pounds tensile strain per sectional inch of iron, deducting 25 per cent for riveted joints.

For steel pipes use 14,000 pounds tensile strain per sectional inch; deduct 25 per cent for riveted joints. Hence, *working pressure for steel pipe* may be taken 40 per cent higher than given in table.

COLUMN NO. 6 is the number of cubic feet of water that will flow through the pipe in one minute, when the velocity of the water is 10 feet per second.

COLUMN NO. 7 is an approximation of the weight of a lineal foot of pipe, including rivets.

The cost of pipe varies with the iron market, and the quantity ordered of one diameter and thickness—

small lots costing sometimes 50 per cent more than large orders.

The charge is extra for dipping pipes in asphaltum—coating them inside and outside—and the cost of dipping small pipes is about one cent for each inch in diameter and one foot in length.

Coating with asphaltum adds about one third of a pound per square foot to the weight of the pipe.

Diameter of Pipe. 1	Area of Pipe. 2	Thickness of Iron in Inches. 3	Thickness of Iron by Wire Gauge. 4	Pressure the Pipe will stand. 5	Cub. Ft. discharged per minute at a velocity of 10 ft. per second. 6	Weight of Pipe per Lineal Foot. 7
3	7	0.035	20	176	29	$1\frac{1}{2}$
3	7	0.049	18	245	29	$2\frac{1}{4}$
4	12.5	0.049	18	183	52	3
4	12.5	0.065	16	243	52	4
5	19.6	0.049	18	147	81	$3\frac{1}{2}$
5	19.6	0.065	16	195	81	5
5	19.6	0.083	14	249	81	$6\frac{1}{4}$
5	19.6	0.109	12	327	81	$8\frac{1}{2}$
6	28	.049	18	122	116	$4\frac{1}{4}$
6	28	.065	16	162	116	$5\frac{3}{4}$
6	28	.083	14	207	116	$7\frac{1}{2}$
6	28	.109	12	272	116	10
7	38	.049	18	105	158	$5\frac{1}{4}$
7	38	.065	16	141	158	$6\frac{3}{4}$
7	38	.093	14	178	158	$8\frac{1}{2}$
7	38	.109	12	234	158	$11\frac{1}{2}$
8	50	.065	16	119	208	$7\frac{1}{2}$
8	50	.083	14	555	208	$9\frac{1}{2}$
8	50	.109	12	204	208	13
8	50	.120	11	225	208	14
8	50	.134	10	252	208	$15\frac{3}{4}$
9	63	.065	16	108	262	$8\frac{1}{2}$
9	63	.083	14	138	262	$10\frac{3}{4}$
9	63	.109	12	182	...	$14\frac{1}{4}$
9	63	.120	11	200	262	16
9	63	.134	10	228	262	$17\frac{1}{2}$
10	78	.065	16	98	313	$9\frac{1}{4}$
10	78	.083	14	125	313	$11\frac{3}{4}$
10	78	.109	12	164	313	$15\frac{3}{4}$
10	78	.120	11	...	313	$17\frac{1}{2}$
10	78	.134	10	201	313	$19\frac{1}{4}$
11	95	.065	16	89	378	$9\frac{3}{4}$
11	95	.083	14	113	378	13
11	95	.109	12	149	378	$17\frac{1}{4}$
11	95	.120	11	162	378	$18\frac{3}{4}$
11	95	.134	10	183	378	21
12	113	.065	16	81	470	$11\frac{1}{4}$
12	113	.083	14	104	470	14
12	113	.109	12	136	470	$18\frac{1}{2}$

1 Diameter of Pipe.	2 Area of Pipe.	3 Thickness of Iron in Inches.	4 Thickness of Iron by Wire Gauge.	5 Pressure the Pipe will stand.	6 Cub. Ft. discharged per minute at a velocity of 10 ft. per second.	7 Weight of Pipe per Lineal Foot.
12	113	.120	11	150	470	19¾
12	113	.134	10	168	470	22¾
12	113	.165	8	206	470	27¾
12	113	.180	7	225	470	32
12	113	.203	6	254	470	36
12	113	.238	4	297	470	41½
13	132	.065	16	75	550	12
13	132	.083	14	93	550	15
13	132	.109	12	114	550	20
13	132	.120	11	138	550	22
13	132	.134	10	155	550	24½
13	132	.165	8	190	550	30
13	132	180	7	207	550	34½
13	132	.203	6	234	550	38½
13	132	.238	4	275	550	42½
14	153	.065	16	69	637	13
14	153	.083	14	89	637	16
14	153	.109	12	117	637	21½
14	153	.120	11	129	637	23½
14	153	.134	10	144	637	26
14	153	.165	8	177	637	32
14	153	.180	7	193	637	37
14	153	.203	6	217	637	41¼
14	153	.238	4	255	637	48
15	176	.065	16	65	733	13¾
15	176	.083	14	83	733	17
15	176	.109	12	109	733	23
15	176	.120	11	120	733	24½
15	176	.134	10	134	733	28
15	176	.165	8	165	733	34¼
15	176	.180	7	180	733	39
15	176	.203	6	203	733	43¾
15	176	.238	4	238	733	51
16	201	.065	16	61	837	14½
16	201	.083	14	78	837	17¼
16	201	.109	12	102	837	24¼
16	201	.120	11	113	837	26½
16	201	.134	10	126	837	29½
16	201	.165	8	155	837	36

Diameter of Pipe. 1	Area of Pipe. 2	Thickness of Iron in Inches. 3	Thickness of Iron by Wire Gauge. 4	Pressure the Pipe will stand. 5	Cub. Ft. discharged per minute at a velocity of 10 ft. per second. 6	Weight of Pipe per Lineal Foot. 7
16	201	.180	7	169	837	41½
16	201	.203	6	190	837	48¼
16	201	.238	4	223	837	54½
18	254	.065	16	54	1058	16½
18	254	.083	14	69	1058	20½
18	254	.109	12	91	1058	27¼
18	254	.120	11	100	1058	30
18	254	.134	10	111	1058	34
18	254	.165	8	138	1058	41
18	254	.180	7	150	1058	46
18	254	.203	6	169	1058	51½
18	254	.238	4	198	1058	60
20	314	.065	16	49	1308	18
20	314	.083	14	63	1308	22½
20	314	.109	12	82	1308	30
20	314	.120	11	90	1308	32½
20	314	.134	10	101	1308	36½
20	314	.165	8	124	1308	44½
20	314	.180	7	135	1308	50¾
20	314	.203	6	153	1308	56¾
20	314	.238	4	179	1308	66
22	380	.065	16	45	1583	20
22	380	.083	14	57	1583	24¾
22	380	.109	12	75	1583	32¾
22	380	.120	11	82	1583	35¾
22	380	.134	10	91	1583	40
22	380	.165	8	112	1583	48¾
22	380	.180	7	123	1583	51
22	380	.203	6	138	1583	62
22	380	.238	4	162	1583	72
24	452	.083	14	52	1883	27¼
24	452	.109	12	68	1883	35½
24	452	.120	11	75	1883	39
24	452	.134	10	84	1883	43½
24	452	.165	8	103	1883	53
24	452	.180	7	112	1883	60
24	452	.203	6	127	1883	67¼
24	452	.238	4	149	1883	78¼
26	530	.083	14	48	2208	29¼

1. Diameter of Pipe.	2. Area of Pipe.	3. Thickness of Iron in Inches.	4. Thickness of Iron by Wire Gauge.	5. Pressure the Pipe will stand.	6. Cub. Ft. discharged per minute at a velocity of 10 ft. per second.	7. Weight of Pipe per Lineal Foot.
26	530	.109	12	63	2208	38½
26	530	.120	11	69	2208	42
26	530	.134	10	78	2208	47
26	530	.165	8	95	2208	57¼
26	530	.180	7	104	2208	64¾
26	530	.203	6	117	2208	72½
26	530	.238	4	138	2208	84
28	615	.083	14	45	2562	31¼
28	615	.109	12	58	2562	41¼
28	615	.120	11	64	2562	45
28	615	.134	10	72	2562	50¼
28	615	.165	8	88	2562	61¼
28	615	.180	7	96	2562	69½
28	615	.203	6	108	2562	77½
28	615	.238	4	127	2562	90½
30	706	.109	12	54	2941	44
30	706	.120	11	60	2941	48
30	706	.134	10	67	2941	54
30	706	.165	8	82	2941	65
30	706	.180	7	90	2941	74
30	706	.203	6	102	2941	83
30	706	.238	4	119	2941	96
30	706	.250	¼	125	2941	101
33	855	.120	11	54	3561	53
33	855	.134	10	61	3561	59
33	855	.165	8	75	3561	72
33	855	.180	7	82	3561	81
33	855	.203	6	93	3561	90
33	855	.238	4	108	3561	105
33	855	.250	¼	113	3561	110
33	855	.259	3	118	3561	115
33	855	.3125	5/16	142	3561	141
30	1017	.120	11	50	4236	58
30	1017	.134	10	56	4236	67
36	1017	.165	8	69	4236	78
36	1017	.180	7	75	4236	88
36	1017	.203	6	84	4236	98
36	1017	.238	4	92	4236	114
36	1017	.250	¼	104	4236	120

Diameter of Pipe. 1	Area of Pipe. 2	Thickness of Iron in Inches. 3	Thickness of Iron by Wire Gauge. 4	Pressure the Pipe will stand. 5	Cub. Ft. discharged per minute at a velocity of 10 ft. per second. 6	Weight of Pipe per Lineal Foot. 7
36	1017	.259	3	108	4236	125
36	1017	.3125	$\frac{5}{16}$	130	4236	153
36	1017	.375	$\frac{3}{8}$	156	4236	186
40	1256	.134	10	51	5232	71
40	1256	.165	8	62	5232	86
40	1256	.180	7	68	5232	97
40	1256	.203	6	76	5232	108
40	1256	.238	4	90	5232	126
40	1256	.250	$\frac{1}{4}$	94	5232	132
40	1256	.259	3	97	5232	138
40	1256	.3125	$\frac{5}{16}$	117	5232	169
40	1256	.375	$\frac{3}{8}$	141	5232	205
42	1385	.134	10	48	5769	74½
42	1385	.165	8	59	5769	91
42	1385	.180	7	64	5769	102
42	1385	.203	6	72	5769	114
42	1385	.238	4	85	5769	133
42	1385	.250	$\frac{1}{4}$	89	5769	137
42	1385	.259	3	92	5769	145
42	1385	.3125	$\frac{5}{16}$	111	5769	177
42	1385	.375	$\frac{3}{8}$	134	5769	216
44	1520	.134	10	45	6332	78
44	1520	.165	8	56	6332	95
44	1520	.180	7	61	6332	106
44	1520	.203	6	69	6332	119
44	1520	.238	4	81	6332	139
44	1520	.250	$\frac{1}{4}$	85	6332	145
44	1520	.259	3	88	6332	151
44	1520	.3125	$\frac{5}{16}$	106	6332	185
44	1520	.375	$\frac{3}{8}$	128	6332	225
48	1809	.134	10	42	7536	85
48	1809	.165	8	51	7536	103
48	1809	.180	7	56	7536	116
48	1809	.203	6	63	7536	130
48	1809	.238	4	75	7536	151
48	1809	.250	$\frac{1}{4}$	78	7536	158
48	1809	.259	3	81	7536	164
48	1809	.3125	$\frac{5}{16}$	98	7536	210
48	1809	.375	$\frac{3}{8}$	117	7536	245

FLOW OF WATER THROUGH RECTANGULAR ORIFICES IN THIN VERTICAL PARTITIONS.

Question: The head being 10 feet, and the gate-opening being 6 inches high and 1 foot wide, what will be the discharge in miners' inches?

Answer: In this table, opposite 10 *feet* in first column, find in column headed "6 inches High, 1 foot Wide," 7.62 cubic feet. Multiply this number by 50, the number of miners' inches in 1 cubic foot, and there results $762 \times 50 = 381.00$ miners' inches.

Question: The head being 25 feet and the opening $1\frac{5}{10}$ inches high, 1 foot wide, how many pounds will be discharged per second?

Answer: In this table, opposite 25 feet in first column, find in column headed "1.5 inches high, 1 foot wide," 3.05 cubic feet. Multiply this number by 62.5, the number of pounds in a cubic foot. $3.05 \times 62.5 = 190.625$ pounds.

Question: The head being 7 feet and the opening 1 inch high, 1 foot wide, what will be the discharge in cubic feet?

Answer: In this table, opposite 7 feet in first column, find, in column headed "3 inches High, 1 foot Wide," 3.24 cubic feet. The given height 1 inch is one third of 3 inches, the height of the opening;

hence, without sensible error, we may take one third the flow due 3 inches for that opening. $3.24 \div 3 = 1.08$.

TABLE SHOWING FLOW OF WATER THROUGH RECTANGULAR ORIFICES IN THIN VERTICAL PARTITIONS.

Head upon Center of Orifice. Feet.	Velocity per Second. Feet.	Breadth and Height of Orifice.									
		1 ft. High. 1 ft. Wide.		9 in. High. 1 ft. Wide.		6 in. High. 1 ft. Wide.		3 in. High. 1 ft. Wide.		1.5 in. High. 1 ft. Wide.	
		Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.	Cubic Feet.	H.P.
0.2	3.58	......	......	......	......	......	......	......	......	.028	.0064
.3	4.40	......	......	......	......	......	......	0.69	.022	.34	.010
.4	5.07	......	......	......	......	1.56	.071	.80	.036	.40	.018
.5	5.67	......	......	2.57	.146	1.74	.099	.89	.051	.45	.026
.6	6.22	3.72	.253	2.83	.193	1.91	.130	.98	.066	.49	.033
.7	6.72	4.02	.317	3.06	.249	2.07	.165	1.06	.082	.53	.041
.8	6.38	4.31	.392	3.27	.297	2.21	.201	1.14	.104	.57	.052
.9	7.62	4.57	.467	3.48	.356	2.35	.240	1.20	.122	.60	.061
1.0	8.025	4.87	.554	3.67	.417	2.48	.281	1.26	.144	.63	.072
1.25	8.99	5.29	.751	4.02	.571	2.71	.385	1.39	.197	.69	.098
1.50	9.83	5.92	1.01	4.50	.767	3.03	.517	1.55	.259	.77	.129
1.75	10.59	6.40	1.27	4.86	.967	3.27	.650	1.67	.326	.83	.163
2.00	11.35	6.85	1.56	5.20	1.18	3.50	.795	1.79	.398	.89	.199
2.25	12.00	7.27	1.86	5.51	1.41	3.71	.949	1.89	.475	.95	.237
2.50	12.68	7.67	2.18	5.81	1.65	3.91	1.11	1.99	.565	1.00	.283
2.75	13.32	8.05	2.53	6.09	1.86	4.10	1.28	2.09	.654	1.04	.327
3.00	13.90	8.41	2.8	6.36	2.17	4.27	1.46	2.18	.743	1.09	.371
3.50	15.01	9.08	3.61	6.86	2.73	4.61	1.83	2.35	.935	1.17	.467
4.00	16.05	9.97	4.54	7.32	3.33	4.92	2.24	2.50	1.14	1.25	.568
4.50	17.02	10.29	5.26	7.75	3.96	5.21	2.66	2.65	1.36	1.32	.678
5.00	17.95	10.84	6.16	8.16	4.64	5.49	3.12	2.78	1.58	1.39	.781
6	19.66	11.84	8.08	8.91	6.08	5.98	4.08	3.03	2.07	1.51	1.03
7	21.23	12.76	10.14	9.61	7.64	6.43	5.12	3.24	2.58	1.62	1.29
8	22.71	13.64	12.40	10.25	9.32	6.84	6.22	3.45	3.14	1.71	1.50
9	24.70	14.47	14.80	10.86	11.11	7.25	7.42	3.64	3.72	1.83	1.82
10	25.38	15.25	17.34	11.44	13.00	7.62	8.66	3.83	4.34	1.92	2.18
15	31.08	18.68	31.85	14.01	23.88	9.34	15.93	4.69	8.00	2.36	4.02
20	35.89	21.50	49.05	16.18	36.78	10.8	24.55	5.42	12.29	2.72	6.15
25	40.13	24.12	68.52	18.10	51.42	12.08	34.32	6.06	17.22	3.05	8.67
30	43.95	26.43	90.10	19.84	67.64	13.47	45.92	6.64	22.64	3.35	11.42
35	47.47	28.55	113.6	21.44	85.27	14.31	56.96	7.18	28.56	3.62	14.40
40	50.75	30.53	138.8	22.94	104.3	15.32	69.64	7.68	34.91	3.79	17.23
45	53.83	32.39	165.6	24.35	124.5	16.26	83.14	8.16	41.73	4.12	21.02
50	56.75	34.15	194.0	25.68	145.8	17.16	97.50	8.61	48.92	4.35	24.72

VOLUMES OF WATER REQUIRED FOR EFFECTIVE USE IN OPERATING HYDRAULIC GIANTS.

Head. Feet.	2-inch Nozzle. Miners' Inches.	2½-inch Nozzle. Miners' Inches.	3-inch Nozzle. Miners' Inches.	4-inch Nozzle. Miners' Inches.	5-inch Nozzle. Miners' Inches.
100	80	125	185	325	500
150	100	155	225	400	625
200	115	180	260	460	715
250	130	200	290	515	800
300	140	220	320	565	880
350	150	240	345	610	950
400	160	255	365	650	1000

The area of circles in square feet may be obtained from the following table,—which is also the number of cubic feet in 1 foot length of the pipe. (Trautwine.)

Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.	Diameter. Inches.	Area. Square Feet.
¼	.0003	3¼	.0576	6¼	.2131
½	.0014	3½	.0668	6½	.2304
¾	.0031	3¾	.0767	6¾	.2485
1	.0055	4	.0873	7	.2673
1¼	.0085	4¼	.0985	7¼	.2867
1½	.0123	4½	.1104	7½	.3068
1¾	.0167	4¾	.1231	7¾	.3276
2	.0218	5	.1363	8	.3491
2¼	.0276	5¼	.1503	8¼	.3712
2½	.0341	5½	.1650	8½	.3941
2¾	.0412	5¾	.1803	8¾	.4176
3	.0491	6	.1964	9	.4418

To Find the Square Root of a Number: Separate the given number into periods of two each, beginning

at unit's place, thus: $1\dot{8}, 6\dot{6}, 2\dot{4}$; or if the number be a decimal fraction, work both right and left from unit's place, thus: $1, \dot{9}6. 1\dot{3}, 6\dot{9}$.

Find the greatest number whose square will go into the first period, and subtract this square; to the remainder annex the next period. Divide this new dividend by twice the square root already found, multiplied by 10 for a trial divisor. The quotient thus found add to the trial divisor: it is the next figure of the root. Multiply this divisor by the last root figure and subtract as in the first instance, etc.

Example.—Find the square root of 186624.

$$
\begin{array}{rr}
 & 18,\ 66,\ 24\ \underline{|432} \\
4 \times 4 = & 16 \\
4 \times 2 = 8 \times 10 = 80 + 3 = 83) & \overline{266} \\
83 \times 3 = & 249 \\
80 + 3 \times 2 = 86 \times 10 = 860 + 2 = 862 & \overline{1724} \\
862 \times 2 = & 1724
\end{array}
$$

Example.—Find the square root of 58.140625.

$$
\begin{array}{rl}
 & \dot{5}8.\ 1\dot{4}\ 0\dot{6}\ 2\dot{5}\ \ \underline{|7.625}\ \textit{Ans.} \\
 & 49 \\
7 \times 2 = 14 \times 10 = 140 + 6 = 146 & \overline{914} \\
146 \times 6 = & 876 \\
 & \overline{.3806}
\end{array}
$$

$$
\begin{array}{l}
140 \\
\underline{12} = 6 \times 2 \\
152 \times 10 = 1520 + 2 = 1522 \\
\qquad\qquad\qquad\qquad 1522 \times 2 = \underline{3044} \\
\qquad\qquad\qquad\qquad\qquad\qquad 76225
\end{array}
$$

$$
\begin{array}{l}
1520 \\
\underline{4} = 2 \times 2 \\
1524 \times 10 = 15240 + 5 = 15245 \\
\qquad\qquad\qquad\qquad 15245 \times 5 = 76225
\end{array}
$$

Example.—Find the square root of 196.1369.

Answer. 14.0048 +.

TABLE OF SAFE HEAD FOR RIVETED HYDRAULIC PIPE.

SHOWING PRICE AND WEIGHT WITH SAFE HEAD FOR VARIOUS SIZES OF DOUBLE-RIVETED PIPE.

Diameter of Pipe in Inches.	Area of Pipe in Inches.	Thickness of Iron by Wire Gauge.	Head in Feet the Pipe will safely stand.	Cub. Ft. of Water Pipe will convey per min. at Vel. 3 ft. per second.	Weight per Lineal Foot in Lbs.	Price per Foot.
3	7	18	400	9	2	$0.20
4	12	18	350	16	2¼	.25
4	12	16	525	16	3	.35
5	20	18	325	25	3½	.35
5	20	16	500	25	4¼	.45
5	20	14	675	25	5	.50
6	28	18	296	36	4¼	.44
6	28	16	487	36	5¾	.50
6	28	14	743	36	7½	.56
7	38	18	254	50	5¼	.50
7	38	16	419	50	6¾	.56
7	38	14	640	50	8½	.63
8	50	16	367	63	7½	.65
8	50	14	560	63	9½	.75
8	50	12	854	63	13	.94
9	63	16	327	80	8½	.69
9	63	14	499	80	10¾	.88
9	63	12	761	80	14¼	1.06
10	78	16	295	100	9¼	.72
10	78	14	450	100	11¾	.82
10	78	12	687	100	15¾	1.00
10	78	11	754	100	17½	1.25
10	78	10	900	100	19¼	1.50
11	95	16	269	120	9¾	.75
11	95	14	412	120	13	.94
11	95	12	626	120	17¼	1.25
11	95	11	687	120	18¾	1.44
11	95	10	820	120	21	1.62
12	113	16	246	142	11¼	.82
12	113	14	377	142	14	1.00
12	113	12	574	142	18½	1.38
12	113	11	630	142	19¾	1.50
12	113	10	753	142	22¾	1.69

SAFE HEAD FOR RIVETED HYDRAULIC PIPE.—(*Continued.*)

Diameter of Pipe in Inches.	Area of Pipe in Inches.	Thickness of Iron by Wire Gauge.	Head in Feet the Pipe will safely stand.	Cub. Ft. of Water Pipe will convey per min. at Vel. 3 ft. per second.	Weight per Lineal Foot in Lbs.	Price per Foot.
13	132	16	228	170	12	$0.90
13	132	14	348	170	15	1.12
13	132	12	530	170	20	1.50
13	132	11	583	170	22	1.65
13	132	10	696	170	24½	1.80
14	153	16	211	200	13	.98
14	153	14	324	200	16	1.17
14	153	12	494	200	21½	1.57
14	153	11	543	200	23½	1.72
14	153	10	648	200	26	1.95
15	176	16	197	225	13¾	.96
15	176	14	302	225	17	1.28
15	176	12	460	225	23	1.75
15	176	11	507	225	24½	1.95
15	176	10	606	225	28	2.10
16	201	16	185	255	14½	1.05
16	201	14	283	255	17¼	1.20
16	201	12	432	255	24¼	1.70
16	201	11	474	255	26½	1.85
16	201	10	567	255	29½	2.00
18	254	16	165	320	16½	1.20
18	254	14	252	320	20½	1.40
18	254	12	385	320	27¼	1.90
18	254	11	424	320	30	2.10
18	254	10	505	320	34	2.40
20	314	16	148	400	18	1.26
20	314	14	227	400	22½	1.54
20	314	12	346	400	30	2.10
20	314	11	380	400	32½	2.25
20	314	10	456	400	36½	2.50
22	380	16	135	480	20	1.40
22	380	14	206	480	24¾	1.70
22	380	12	316	480	32¾	2.25
22	380	11	347	480	35¾	2.45
22	380	10	415	480	40	2.80
24	452	14	188	570	27¼	1.80
24	452	12	290	570	35½	2.35
24	452	11	318	570	39	2.70
24	452	10	379	570	43½	2.95
24	452	8	466	570	53	3.50

SAFE HEAD FOR RIVETE DHYDRAULIC PIPE.—(*Continued.*)

Diameter of Pipe in Inches.	Area of Pipe in Inches.	Thickness of Iron by Wire Gauge.	Head in Feet the Pipe will safely stand.	Cub. Ft. of Water Pipe will convey per min. at Vel. 3 ft. per second.	Weight per Lineal Foot in Lbs.	Price per Foot.
26	530	14	175	670	29¼	$2.00
26	530	12	267	670	38½	2.59
26	530	11	294	670	42	2.87
26	530	10	352	670	47	3.10
26	530	8	432	670	57¼	3.85
28	615	14	102	775	31¼	2.12
28	615	12	247	775	41¼	2.75
28	615	11	273	775	45	3.00
28	615	10	327	775	50¼	3.20
28	615	8	400	775	61¼	4.15
30	706	12	231	890	44	2.90
30	706	11	254	890	48	3.15
30	706	10	304	890	54	3.50
30	706	8	375	890	65	4.30
30	706	7	425	890	74	4.75
36	1017	11	141	1300	58	3.80
36	1017	10	155	1300	67	4.30
36	1017	8	192	1300	78	5.10
36	1017	7	210	1300	88	5.75
40	1256	10	141	1600	71	4.75
40	1256	8	174	1600	86	5.60
40	1256	7	189	1600	97	6.40
40	1256	6	213	1600	108	7.35
40	1256	4	250	1600	126	8.50
42	1385	10	135	1760	74½	5.05
42	1385	8	165	1760	91	6.20
42	1385	7	180	1760	102	7.00
42	1385	6	210	1760	114	7.80
42	1385	4	240	1760	133	9.00
42	1385	¼	270	1760	137	9.50
42	1385	3	300	1760	145	10.00
42	1385	$\frac{5}{16}$	321	1760	177	12.00
42	1385	$\frac{3}{8}$	363	1760	216	15.00

NOTE.—Where formed and punched including rivets, for mule packing or to facilitate transportation by other means, 30 per cent may be deducted from prices above given. This list is based upon pipe coated inside and out with asphaltum, and is given for the purpose of enabling parties to make an approximate estimate of the cost. Net prices will be quoted on application,

TABLE OF VELOCITIES.

Head in Feet.	Velocity, Feet per Second.	Actual Velocity, Feet per Second.	Discharge per Second through Nozzles.							
			1″	2″	3″	4″	5″	6″	7″	8″
10	25.4	26.32	11.18	44.30	99.78	177.4	277.0	399.1	682.2	709.4
20	35.9	28.72	15.79	62.61	141.0	250.8	391.4	564.1	767.7	1026
30	43.9	35.12	19.32	76.56	173.9	306.6	478.7	689.7	938.8	1226
40	50.7	40.56	22.31	89.24	199.3	354.1	552.8	796.7	1085	1416
50	56.7	45.36	24.95	98.88	222.7	396.0	618.4	890.9	1213	1584
60	62.1	49.68	27.33	108.30	243.9	433.7	677.1	975.7	1328	1735
70	67.1	53.68	29.52	117.01	263.5	468.6	731.7	1053	1435	1874
80	71.8	57.44	31.66	125.24	282.0	501.5	783.9	1129	1535	2005
90	76.1	60.88	33.49	132.87	298.9	531.4	829.8	1196	1627	2126
100	80.3	64.24	35.33	140.32	308.9	560.8	874.6	1262	1717	2243
110	84.2	67.36	37.05	146.82	330.8	588.0	918.1	1323	1801	2352
120	87.96	70.36	38.70	153.48	345.5	614.3	959.0	1382	1881	2456
130	91.54	73.23	40.28	159.92	359.5	639.3	998.1	1439	1958	2556
140	94.99	75.99	41.80	165.73	373.1	663.4	1036	1493	2031	2653
150	98.3	78.64	43.26	171.54	386.1	686.5	1072	1545	2102	2745
160	101.49	81.19	44.65	177.26	398.5	708.8	1107	1595	2170	2834
170	104.56	83.62	45.99	182.36	410.5	718.4	1140	1643	2236	2919
180	107.76	86.20	47.41	188.16	423.2	752.5	1176	1693	2305	3009
190	110.65	88.52	48.69	192.92	434.7	772.8	1207	1739	2366	3091
200	113.54	90.83	49.94	198.16	446.0	793.0	1238	1784	2428	3171
210	116.35	93.08	51.20	203.80	457.0	812.6	1259	1828	2488	3250
220	119.08	95.26	52.49	207.82	467.8	831.7	1299	1872	2547	3326
230	121.73	97.38	53.56	212.33	478.1	850.1	1323	1913	2604	3400
240	124	99.2	54.56	216.2	487.0	866.0	1352	1948	2652	3463
250	126	100.8	55.44	219.8	495.0	888.0	1374	1980	2694	3519
260	129	103.2	56.76	225.0	560.7	900.9	1407	2027	2759	3603
270	131	104.8	57.64	228.5	514.6	914.9	1428	2059	2801	3649
280	134	107.2	58.96	233.7	526.3	935.9	1461	2105	2865	3742
290	136	108.8	59.84	237.7	534.1	949.9	1483	2127	2909	3798
300	139	111.2	60.32	239.1	538.8	957.5	1495	2154	2932	3819
310	141	112.8	61.64	240.3	541.2	962.3	1503	2165	2947	3835
320	143	114.4	62.92	249.4	561.7	998.8	1559	2246	3058	3993
330	145	116.0	63.80	252.9	569.6	1012	1585	2278	3100	4050
340	148	118.4	64.61	256.1	576.8	1025	1601	2307	3140	4101
350	150	120.0	66.00	261.6	589.2	1047	1635	2357	3207	4189
360	152	121.6	66.88	262.5	597.1	1062	1658	2388	3245	4245
370	154	123.2	67.76	265.1	604.9	1075	1679	2419	3293	4301
380	156	124.8	68.64	272.1	612.8	1090	1701	2449	3336	4358
390	158	126.4	69.52	275.6	620.6	1104	1723	2482	3402	4412
400	160	128.0	70.40	279.0	628.5	1117	1746	2514	3422	4468
410	162	129.6	71.28	282.5	636.3	1132	1767	2545	3462	4523
420	164	131.2	72.11	285.8	643.7	1144	1787	2574	3505	4573
430	166	132.8	73.04	289.5	652.0	1160	1790	2608	3539	4586
440	168	134.4	73.92	293.0	659.9	1174	1832	2640	3593	4692
450	170	136.0	74.80	296.4	667.8	1188	1854	2672	3635	4747

TABLE FOR WEIR MEASUREMENT,

GIVING CUBIC FEET OF WATER PER MINUTE THAT WILL FLOW OVER A WEIR 1 INCH WIDE AND FROM $\frac{1}{8}$ TO $20\frac{7}{8}$ INCHES DEEP.

Inches.		⅛	¼	⅜	½	⅝	¾	⅞
0	.00	.01	.05	.09	.14	.19	.26	.32
1	.40	.47	.55	.64	.73	.82	.92	1.02
2	1.13	1.23	1.35	1.46	1.58	1.70	1.82	1.95
3	2.07	2.21	2.34	2.48	2.61	2.76	2.90	3.05
4	3.20	3.35	3.50	3.66	3.81	3.97	4.14	4.30
5	4.47	4.64	3.81	4.98	5.15	5.33	5.51	5.69
6	5.87	6.06	6.25	6.44	6.62	6.82	7.01	7.21
7	7.40	7.60	7.80	8.01	8.21	8.42	8.63	8.83
8	9.05	9.26	9.47	9 69	9.91	10.13	10.35	10.57
9	10.80	11.02	11.25	11.48	11.71	11.94	12.17	12.41
10	12.64	12.88	13.12	13.36	13.60	13.85	14.09	14.34
11	14.59	14.84	15.09	15.34	15.59	15 85	16.11	16.36
12	16.62	16.88	17.15	17.41	17.67	17.94	18.21	18.47
13	18.74	19.01	19.29	19.56	19.84	20.11	20.39	20.67
14	20.95	21.23	21.51	21.80	22.08	22.37	22.65	22.94
15	23.23	23.52	23.82	24.11	24.40	24.70	25.00	25.30
16	25.60	25.90	26 20	26.50	26.80	27.11	27.42	27.72
17	28.03	28.34	28.65	28.97	29.28	29.59	29.91	30.22
18	30.54	30.86	31.18	31.50	31.82	32.15	32.47	32.80
19	33.12	33.45	33.78	34.11	34.44	34.77	35.10	35.44
20	35.77	36.11	36.45	36.78	37.12	37.46	37.80	38.15

LOSS OF HEAD IN PIPE BY FRICTION.

The following tables show the loss of head by friction in each 100 feet in length of different diameters of pipe when discharging the following quantities of water per minute:

Velocity in Feet per Sec.	Inside Diameter of Pipe in Inches.											
	1		2		3		4		5		6	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet	Cubic Feet per Min.
2.0	2.37	.65	1.185	2.62	.791	5.89	.593	10.4	.474	16.3	.395	23.5
2.2	2.80	.73	1.404	2.88	.936	6.48	.702	11.5	.561	18	.468	25.9
2.4	3.27	.79	1.639	3.14	1.093	7.07	.819	12.5	.650	19.6	.547	28.2
2.6	3.78	.86	1.891	3.40	1.26	7.65	.945	13.6	.757	21.3	.631	30 6
2.8	4.32	.92	2.16	3.66	1.44	8.24	1.080	14 6	.864	22.9	.720	32.9
3.0	4.89	.99	2.44	3.92	1.62	8.83	1.22	15.7	.978	24.5	.815	35.3
3.2	5.47	1.06	2.73	4.18	1.82	9.42	1.37	16.7	1.098	26.2	.915	37.7
3.4	6.09	1.12	3.05	4.45	2.04	10.00	1.52	17.8	1.22	27.8	1.021	40
3.6	6.76	1.19	3.38	4.71	2.26	10.60	1.69	18.8	1.35	29.4	1.131	42.4
3.8	7.48	1.26	3.74	4.97	2.49	11.20	1.87	19.9	1.49	31	1.25	44.7
4.0	8.20	1.32	4.10	5.23	2.73	11.80	2.05	20.9	1.64	32.7	1.37	47.1
4.2	8.97	1.39	4.49	5.49	2.98	12.30	2.24	22.0	1.79	34.3	1.49	49.5
4.4	9.77	1.45	4.89	5.76	3.25	12.90	2.43	23.0	1.95	36.0	1.62	51.8
4.6	10.60	1.52	5.30	6.02	3.53	13.50	2.64	24.0	2.11	37.6	1.76	54.1
4.8	11.45	1.58	5.72	6.28	3.81	14.10	2.85	25.1	2.27	39.2	1.90	56.5
5.0	12.33	1.65	6.17	6.54	4.11	14.70	3.08	26.2	2.46	40.9	2.05	58.9
5.2	13.24	1.72	6.62	6.80	4.41	15.30	3.31	27.2	2.65	42.5	2.21	61.2
5.4	14.20	1.78	7.10	7.06	4.73	15 90	3.55	28.2	2.84	44.2	2.37	63.6
5.6	15.16	1.85	7.58	7.32	5.06	16.50	3.79	29.3	3.03	45.8	2.53	65.9
5.8	16.17	1.91	8.09	7.58	5.40	17.10	4.04	30.3	3.24	47.4	2.70	68.3
6.0	17.23	1.98	8.61	7.85	5.74	17.70	4.31	31.4	3.45	49.1	2.87	70.7
7.0	22.89	2.31	11.45	9.16	7.62	20.60	5.72	36.6	4.57	57.2	3.81	82.4

LOSS OF HEAD IN PIPE BY FRICTION—(*Continued.*)

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	7		8		9		10		11		12	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.338	32.0	.296	41.9	.264	53	.237	65.4	.216	79.2	.198	94.2
2.2	.401	35.3	.351	46.1	.312	58.3	.281	72	.255	87.1	.234	103
2.4	.468	38.5	.410	50.2	.365	63.6	.327	78.5	.297	95.0	.273	113
2.6	.540	41.7	.473	54.4	.420	68.9	.378	85.1	.344	103	.315	122
2.8	.617	44.9	.540	58.6	.480	74.2	.432	91.6	.392	111	.360	132
3.0	.698	48.1	.611	62.8	.544	79.5	.488	98.2	.444	119	.407	141
3.2	.785	51.3	.686	67	.609	84.8	.549	105	.499	127	.457	151
3.4	.875	54.5	.765	71.2	.680	90.1	.612	111	.557	134	.510	160
3.6	.969	57.7	.848	75.4	.755	95.4	.679	118	.617	142	.566	169
3.8	1.070	60.9	.936	79.6	.831	101	.749	124	.680	150	.624	179
4.0	1.175	64.1	1.027	83.7	.913	106	.822	131	.747	158	.685	188
4.2	1.28	67.3	1.122	87.9	.998	111	.897	137	.816	166	.749	198
4.4	1.39	70.5	1.22	92.1	1.086	116	.977	144	.888	174	.815	207
4.6	1.51	73.7	1.32	96.3	1.177	122	1.059	150	.963	182	.883	217
4.8	1.63	76.9	1.43	100.0	1.27	127	1.145	157	1.040	190	.954	226
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6.0	2.46	96.2	2.15	125	1.92	159	1.71	196	1.56	237	1.43	283
7.0	3.26	112.0	2.85	146	2.52	185	2.28	229	2.07	277	1.91	330

LOSS OF HEAD IN PIPE BY FRICTION—(*Continued.*)

Velocity in Feet per Sec.	13		14		15		16		18		20	
	Loss of Head in Feet.	Cubic Feet. per Min.	Loss of Head in Feet.	Cubic Feet. per Min.	Loss of Head in Feet.	Cubic Feet. per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.183	110	.169	128	.158	147	.147	167	.132	212	.119	262
2.2	.216	121	.200	141	.187	162	.175	184	.156	233	.140	288
2.4	.252	133	.234	154	.218	176	.205	201	.182	254	.164	314
2.6	.290	144	.270	167	.252	191	.236	218	.210	275	.189	340
2.8	.332	156	.308	179	.288	206	.270	234	.240	297	.216	366
3.0	.375	166	.349	192	.325	221	.306	251	.271	318	.245	393
3.2	.422	177	.392	205	.366	235	.343	268	.305	339	.275	419
3.4	.471	188	.438	218	.408	250	.383	284	.339	360	.306	445
3.6	.522	199	.485	231	.452	265	.425	301	.377	382	.339	471
3.8	.576	210	.535	243	.499	280	.468	318	.416	403	.374	497
4.0	.632	221	.587	256	.548	294	.513	335	.456	424	.410	523
4.2	.691	232	.641	269	.598	309	.561	352	.499	445	.449	550
4.4	.751	243	.698	282	.651	324	.611	368	.542	466	.488	576
4.6	.815	254	.757	295	.707	339	.662	385	.588	488	.529	602
4.8	.881	265	.818	308	.763	353	.715	402	.636	509	.572	628
5.0	.949	276	.881	321	.822	368	.770	419	.685	530	.617	654
5.2	1.020	287	.947	333	.883	383	.828	435	.736	551	.662	680
5.4	1.092	298	1.014	346	.947	397	.888	452	.788	572	.710	707
5.6	1.167	309	1.083	359	1.011	412	.949	469	.843	594	.758	733
5.8	1.245	321	1.155	372	1.078	427	1.011	486	.899	615	.809	759
6.0	1.325	332	1.229	385	1.148	442	1.076	502	.957	636	.861	785
7.0	1.75	387	1.63	449	1.52	515	1.43	586	1.27	742	1.143	916

LOSS OF HEAD IN PIPE BY FRICTION—(*Continued.*)

Velocity in Feet per Sec.	22		24		26		28		30		56	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.108	316	.098	377	.091	442	.084	513	.079	589	.066	848
2.2	.127	348	.116	414	.108	486	.099	564	.093	648	.078	933
2.4	.149	380	.136	452	.126	531	.116	616	.109	707	.091	1018
2.6	.171	412	.157	490	.145	575	.134	667	.126	766	.104	1100
2.8	.195	443	.180	528	.165	619	.153	718	.144	824	.119	1188
3.0	.222	475	.204	565	.188	663	.174	770	.163	883	.135	1273
3.2	.249	507	.229	603	.211	708	.195	821	.182	942	.152	1357
3.4	.278	538	.255	641	.235	752	.218	872	.204	1001	.169	1442
3.6	.308	570	.283	678	.261	796	.242	923	.226	1060	.188	1527
3.8	.340	601	.312	716	.288	840	.267	974	.249	1119	.207	1612
4.0	.373	633	.342	754	.315	885	293	1026	.273	1178	.228	1697
4.2	.408	665	.374	791	.345	929	.320	1077	.299	1237	.249	1782
4.4	.444	697	.407	829	.375	973	.348	1129	.325	1296	.271	1866
4.6	.482	728	.441	867	.407	1017	.378	1180	.353	1355	.294	1951
4.8	.521	760	.476	905	.440	1062	.409	1231	.381	1414	.318	2036
5.0	.561	792	.513	942	.474	1106	.440	1283	.411	1472	.312	2121
5.2	.602	823	.552	980	.510	1150	.473	1334	.441	1531	.368	2206
5.4	.645	855	.591	1018	.546	1194	.507	1385	.473	1590	.394	2291
5.6	.690	887	.632	1055	.583	1239	.542	1437	.506	1649	.421	2376
5.8	.735	918	.674	1093	.622	1283	.578	1488	.540	1708	.450	2460
6.0	782	950	.717	1131	.662	1327	.615	1539	.574	1767	.479	2545
7.0	1.040	1109	.953	1319	.879	1548	.817	1796	.762	2061	.636	2868

Example.—Have 200 feet head and 600 feet of 11-inch pipe, carrying 119 cubic feet of water per minute. To find effective head: In right-hand column under 11-inch pipe find 119 cubic feet; opposite this will be found the coefficient of friction for this amount of water, which is .444. Multiply this by the number of hundred feet of pipe, which is 6, and you will have 2.66 feet, which is the loss of head. Therefore the effective head is 200−2.66 = 197.34.

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